DOCUMENT RESUME

ED 107 698 TM 004 522

AUTHOR	Shriver, Edgar L.; Foley, John P., Jr.
TITLE	Evaluating Maintenance Performance: The Development and Tryout of Criterion Referenced Job Task Performance Tests for Electronic Maintenance. Final Report for Period January 1969-May 1974.
INSTITUTION	Air Force Human Resources Lab., Wright-Patterson AFB, Ohio. Advanced Systems Div.; URS Systems Corp., Falls Church, Va. Matrix Research Div.
SPONS AGENCY	Air Force Human Resources Lab., Brooks AFB, Texas.
REPORT NO	AFHRL-TR-74-57(II)
PUB DATE	Sep 74
NOTE	111p.; For related documents, see TM 004 444, 643, 644 and 645
EDRS PRICE	MF-$0.76 HC-$5.70 PLUS POSTAGE
DESCRIPTORS	*Criterion Referenced Tests; Electronic Equipment; *Electronics; *Equipment Maintenance; Military Personnel; Models; *Performance Tests; Scoring; Task Performance; *Test Construction
IDENTIFIERS	*Air Force

ABSTRACT

A battery of criterion referenced job task performance tests (JIPT) for typical electronic maintenance activities were developed. The construction of a battery of such tests together with an appropriate scoring for reporting the results is detailed. The development of a Test Administrators Handbook also is described. This battery is considered to be a model for future criterion JTPT development and is intended for both formal training and field use. The battery includes separate tests for the following classes of job activities: (1) equipment checkout, (2) alignment/calibration, (3) removal/replacement, (4) soldering, (5) use of general and special test equipment, and (6) troubleshooting. (Author/BJG)

To TM

AFHRL-TR-74-57(II),
Part I

AIR FORCE

HUMAN RESOURCES

ED107698

EVALUATING MAINTENANCE PERFORMANCE:

THE DEVELOPMENT AND TRYOUT OF CRITERION REFERENCED JOB TASK PERFORMANCE TESTS FOR ELECTRONIC MAINTENANCE

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September 1974
Final Report for Period 1 January 1969 – 3 May 1974

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This final report was submitted by Advanced Systems Division, Air Force Human Resources Laboratory (AFSC), Wright-Patterson Air Force Base, Ohio 45433, under project 1710. It is a compilation and expansion of materials submitted by URS/Matrix Research Company, Falls Church, Virginia 22042 under Contracts F33615-69C-1232 and F33615-70C-1695. Dr. John P. Foley and Mr. John K. Klesch, Advanced Systems Division, shared the contract monitorship.

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This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFHRL-TR-74-57(II), Part I	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EVALUATING MAINTENANCE PERFORMANCE: THE DEVELOPMENT AND TRYOUT OF CRITERION REFERENCED JOB TASK PERFORMANCE TESTS FOR ELECTRONIC MAINTENANCE		5. TYPE OF REPORT & PERIOD COVERED Final 1 January 1969 – 3 May 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Edgar L. Shriver John P. Foley, Jr.		8. CONTRACT OR GRANT NUMBER(s) F33615-69C-1232 F33615-70C-1695
9. PERFORMING ORGANIZATION NAME AND ADDRESS URS/Matrix Research Company 7245 Arlington Boulevard Falls Church, Virginia 22042		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62703F 17100416, 17101003, 17101006
11. CONTROLLING OFFICE NAME AND ADDRESS Hq Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE September 1974
		13. NUMBER OF PAGES 112
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Advanced Systems Division Air Force Human Resources Laboratory Wright-Patterson Air Force Base, Ohio 45433		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Volumes I, III, and IV of this report in press.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Job Task Performance Tests
Criterion referenced tests
video testing
maintenance effectiveness
Personnel selection
psychology – individual and group
measurement and evaluation technical training
measurement and evaluation maintenance training
measurement and evaluation electronics training
measurement and evaluation vocational education

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The previous Volume, AFHRL-TR-74-57(I), recommended the development of criterion referenced Job Task Performance Tests (JTPT) for typical electronic maintenance activities. This Volume reports the development of a battery of such tests together with an appropriate scoring scheme for reporting the results of administering them. The development of a Test Administrators Handbook also is described. This battery is considered to be a model for future criterion JTPT development and is intended for both formal training and field use.

The battery includes separate tests for the following classes of job activities: (1) equipment checkout, (2) alignment/calibration, (3) removal/replacement, (4) soldering, (5) use of general and special test equipment, and (6) troubleshooting. The DopplerRadar, the AN/APN-147 and its computer the AN/ASN-35 were selected as a typical

Item 20 (Continued)

electronic system. This system was used as the test bed for this model battery. The soldering and general test equipment JTPT are applicable to all electronic technicians. The other tests of the battery apply to technicians concerned with this specific doppler radar system.

Each class of activity for which JTPT were developed contains its individual mix of behaviors, but it is not mutually exclusive. There are dependencies among the classes. As a result a four level hierachy of dependencies can be stated: (1) checkout, removal/replacement, and soldering; (2) use of general and special test equipment; (3) alignment/calibration; and (4) troubleshooting. For example, troubleshooting may include all the activities mentioned before it.

Due to the diverse character of the various mixes of behaviors involved in each class of maintenance activity, a single score report of test results would be meaningless. A profile of test results therefore was developed which provides for an individual cell for each test problem. The tests are structured so that each problem produces a product. The results for each problem is reported in terms of a go, no-go score. Either the test subject produces a satisfactory *product* or he does not. Where *time* is important, he must produce the satisfactory product in a specified time. Although *process* may be valuable as a diagnostic tool, it is not considered as an appropriate factor for scoring purposes.

The hierachy of dependencies mentioned previously has implication for the order in which tests are administered as well as for diagnostics. For example, since troubleshooting includes the use of test equipment and other activities in the hierachy, logic would dictate that administration of the tests for the sub-activities would precede the troubleshooting tests and that a test subject would not be permitted to take the troubleshooting tests until he had passed these other subtest.

Due to the unavailability of a sufficient number of experienced test subjects at the time of the tryout of the JTPT battery, the tryout was not as extensive as planned. The limited tryout did indicate that the tests as developed are administratively feasible. There continued use, no doubt, would result in further modifications and polish. The report also includes a discussion of several implementation considerations and suggestions.

SUMMARY

Problem

The in-depth review of the literature reported in Volume I of this series of reports strongly reiterated the fact that paper and pencil tests of job knowledge and electronic theory tests have very poor criterion-related or empirical validity with respect to the ability of electronic maintenance men for performing their job tasks. This literature review, also produced little evidence that anything was being accomplished in a systematic way to develop adequate job measures. Most of the reported test efforts were of the "ad hoc" variety. Such tests usually covered only parts of the maintenance job and attempted to report results in terms of a single score, providing little diagnostic information. Another facet of this problem was that even though criterion-referenced job performance tests were recognized as being superior by many training people, paper and pencil tests were substituted because they were more easily and cheaply developed and administered.

Approach

Hypotheses were suggested for improving the job coverage and scoring of Job Task Performance Tests (JTPT) and for developing symbolic substitute tests that would have higher empirical validity than the traditional paper and pencil job knowledge tests. Such symbolic substitutes could not be developed until good JTPT were available as criteria. This effort was aimed at the development of such criterion tests. The hypotheses that were offered for improving JTPT included the following:

1. Separate tests could be developed for each type of job activity. The activities to be considered were checkout procedures; align, adjust, and calibrate activities; remove and replace activities; troubleshooting; use of test equipment; and use of hand tools.

2. A separate and appropriate scoring and diagnostic scheme could be developed for reporting the results from each type of test.

Based on these hypotheses plans were made to develop a battery of JTPT together with appropriate scoring schemes for each type of electronic maintenance activity. The doppler radar, the AN/APN-147 and its computer, the AN/ASN-35, were selected as typical equipments for test development. These plans called for a testing system that could be administered by personnel that were not experts in the maintenance of these equipments. The system was to include the JTPT, an administrator's handbook, and a training program for test administrators. This system was to be considered as model for the development of future tests for measuring ability to perform *electronic* maintenance tasks. The model was to be appropriate for use in field maintenance units, for use in training, and for use in research projects. The plans called for a rather extensive tryout of this testing system in field maintenance units in the Military Airlift Command (MAC).

Results

A model JTPT system was developed. This system included 48 JTPT that covered the typical organizational and intermediate maintenance activities mentioned; and administrator's manual in step-by-step format and a training program for Air Force administrators. The training program was given successfully to members of the MAC maintenance standardization team. Each test was administered successfully at least seven times to experienced Air Force maintenance personnel. Due to fewer standardization team field visits than planned during the tryout period and to a "non-interference" policy for the MAC standardization team, the plans to gather additional hard data concerning electronic technicians' job abilities were not achieved.

As to the scoring scheme, product, process and time were considered as to their appropriateness. A test subject has not reached criterion on a task until he has produced a complete satisfactory *product*. This is a go, no-go criterion. In most cases, time is not a critical factor but for some organizational (flight line) tasks it might be. Where time is critical, the subject must produce this product within a prescribed time. Otherwise, he must produce his product in a reasonable time. The product for each type of test will of course be somewhat different. Process information was not considered an appropriate basis for a score but such information may be used for diagnostic purposes. During the test development and tryout it became apparent that the activities were not mutually exclusive. These activities can be arranged in a four level hierachy of dependencies as follows:

1. Check out; remove and replace; and soldering activities.
2. Use of general and special test equipment.
3. Align, adjust, and calibrate activities.
4. Troubleshooting.

This hierarchy of dependencies among activities together with the go, no-go product criterion for each test problem made possible the development of a diagnostic profile for reporting test results (Figures 10 and 11).

In addition to the reporting of the development and tryout of the JTPT system, the report discusses other relevant factors concerning the development and implementation of JTPT. Some examples follow. The soldering tests and the tests on use of general equipment have general application from equipment to equipment, whereas the other tests are equipment specific. Current personnel and training systems are built around paper and pencil testing practice but an orderly modification of training and testing practice is possible.

Conclusions

The tryout of the JTPT system indicated that the system is an adequate model for JTPT on other equipments, that Air Force Maintenance Technicians can be successfully trained as test administrators and that they are able to administer tests to Air Force Maintenance personnel. The tests on soldering and use of general test equipment together with appropriate training packages can be used in the field electronic maintenance shops and in formal and on-the-job training programs. These actions can be accomplished with a minimum of modifications of current Air Force maintenance and training programs. Such action would result in great benefit to the Air Force. The use of equipment specific tests in the field and in training would require a much more expensive test development program and an extensive modification of training and maintenance procedures. But until maintenance, training and personnel specialists and administrators accept and understand the fact that most paper and pencil job knowledge tests and theory tests have extremely *low* empirical validity, we can expect no large scale shift to JTPT.

PREFACE

This document represents a portion of the Exploratory Development program of the Advanced Systems Division of the Air Force Human Resources Laboratory. It is a compilation and expansion of materials submitted by URS/Matrix Research Company, Falls Church, Virginia 22042 under contracts F33615-69C-1232 and F33615-70C-1695. Dr. Edgar L. Shriver was the Principal Investigator.

This document is Part I of the second volume (AFHRL-TR-74-57(II), Part I) of a four volume report to be published concerning the evaluation of maintenance performance. The other documents are entitled:

1. *Evaluating Maintenance Performance: An Analysis*. AFHRL-TR-74-57(I). In press.

2. *Evaluating Maintenance Performance: Test Administrator's Manual and Test Subject's Instructions for Criterion Referenced Job Task Performance Tests for Electronic Maintenance*. AFHRL-TR-74-57(II), Part II. In press.

3. *Evaluating Maintenance Performance: The Development of Graphic Symbolic Substitutes for Criterion Referenced Job Task Performance Tests for Electronic Maintenance*. AFHRL-TR-74-57(III). In press.

4. *Evaluating Maintenance Performance: A Video Approach to Symbolic Testing of Electronic Maintenance Tasks*. AFHRL-TR-74-57(IV). In press.

The preparation of all these documents has been documented under task area and work unit 171010, Evaluating the Performance of Air Force Operators and Technicians of Project 1710, Training for Advanced Air Force Systems. Identification of this document by work units included work units 17101003, 17100416 and 17101006. Dr. John P. Foley was task scientist. Dr. John P. Foley and Mr. John K. Klesch of the Advanced Systems Division shared the contract monitorship. Dr. Ross L. Morgan was the Project Scientist.

The authors wish to acknowledge the cooperation and assistance of many individuals who contributed to this effort. Mr. John F. Hayes and Mr. William R. Hufhand of URS/Matrix Research Company expended a great deal of effort during the development and tryout of the Job Task Performance Test (JTPT) system. At various stages during the planning, development and tryout many Military Airlift Command people were involved. Some of the MAC Headquarters personnel that should be mentioned include Col Donald H. Watt, Lt Col Shelby Corpsman, Lt Col Lloyd B. McKeethen, Capt Gary E. Clark, Capt Warren E. Spenser, Capt Robert A. Letz, Special mention is due to CMS Jack Brown and SMS John Beaucher of the MAC Maintenance Standardization Team who served as test administrators. At McGuire AFB, Col Gerald Auger, Lt Col Edward Kaiatt, CMS Wilbur Easey, CMS James Townes, Mr. Milton Wills and Mr. David Bond. At Norton AFB, Lt Col Leon Creed. At Altus AFB, Maj Louis P. Gerac and Capt Stephen R. Millers. Mr. John K. Klesch of the Advanced Systems Division, AFHRL, must be thanked for his contributions as well as for his several extended trips to operational sites. Dr. Ross L. Morgan and Dr. Gordon A. Eckstrand provided many helpful suggestions.

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EVAULATING MAINTENANCE PERFORMANCE: THE DEVELOPMENT AND TRYOUT OF CRITERION REFERENCED JOB TASK PERFORMANCE TESTS FOR ELECTRONIC MAINTENANCE

SECTION I. TEST DEVELOPMENT METHODOLOGY

Introduction

In AFHRL-TR-74-57(I) of this series of reports, the background of evaluating technical personnel was described and the case for performance based evaluations made. AFHRL TR-74-57(I) therefore is recommended as a valuable prelude for a fuller appreciation of this volume. Based on that report, this project was undertaken to develop a series of criterion referenced performance tests that achieve valid evaluations of readiness, training on-the-job performance, job performance aids, and other new concepts for the maintenance process.

The main thrust of the efforts reported in this volume was for the development of an administratively feasible battery of criterion referenced Job Task Performance Tests (JTPT) and adequate scoring schemes for the key tasks of electronic maintenance jobs. The types of such key tasks considered are outlined in AFHRL-TR-74-57(I) and include checkout, use of hand-tools, use of general and special test equipment, remove/replace, align/adjust/calibrate, and troubleshooting. The hand-tools and general test equipment JTPT concern activities which have general use among all electronic technicians. Although the battery was developed as a model, the remainder of the tests is systems specific to the doppler radar, the AN/APN-147, and its computer, the AN/ASN-35. The battery as developed includes 48 tests.

During and after development each of these tests was administered at least seven times to insure its administrative feasibility. This administrative feasibility requirement was achieved. *Since these tests were designed to be as near to the ultimate job criterion as possible, no validation of their empirical validity was possible or necessary. The tests are empirically valid by definition.* Original plans called for additional field administrations of the battery for the purpose of obtaining some hard data on how well technicians can perform the key tasks of their jobs. Unfortunately, due to lack of subject time, this desirable secondary objective was not achieved.

JTPT, in the context of this report, refer specifically to evaluating an individual's ability to perform a task that has been identified as a component of his present or anticipated job. In this rationale, no "knowledges" are separately tested. They may be applied or not applied. What is tested is the ability to perform the task, and the evidence is a completed job product which meets job specifications. The test subject may have used knowledges and physical skills to produce that product, but no attempt is made in these tests to separate the knowledge and skill components for individual evaluation. Ability to perform the job task in such a way as to produce the job task products is accepted as prima facie evidence of possession of requisite knowledges.

In addition to measuring ability to perform job tasks, these performance tests were also to be developed so as to provide "diagnostic" information. The test should be able to provide some indication of the specific nature of a performance deficiency even though the test does not assign scores to factors contributing to over-all performance.

The training/testing milieu into which the products of a project such as this one will fit can be described as "job-referenced," "performance-oriented," or "criterion referenced." That is, the prime emphasis of such a system will be the production of personnnel equipped with the necessary training, job-aids, and techniques to permit them to accomplish assigned job tasks under operational conditions. The criterion of performance is production of *products* which meet job specifications. This is a "go, no-go" criterion for the production of each job product.

Objectives

Based on the discussion in AFHRL-TR-74-57(I) and the preceding discussion, the objective of this project was to develop as a model a set of JTPT that serve the purposes specified and have the following characteristics.

Job Relevance or Empirical Validity. Performance is evaluated by inspecting the *job products* of each task performed in the test. If the job products *are* those required on the job, then the test *is* job relevant. There is no more ultimate test of test validity than this.

Scorability. Each test item must be scorable *objectively*. The score for each item should indicate whether the task has been correctly performed or not (go, no-go). The score is given when the job *product* of the task performed meets job specifications. If the product does not meet specifications no score is given for the test item no matter how much of the performance *process* was "correct." The criterion of performance is in the product. The score is not given for correctly performing steps in the job process, but only for producing a job product according to job specifications. Under certain conditions, "time to perform" may become part of a task "go, no-go" specification.

Representativeness. A job requires numerous kinds of products, processes or inputs. It is not feasible to test for all. But each kind must be tested in order to determine if the test subject is capable in all these areas. The test constructor must state which kinds of tasks the test tests. But he cannot prove that there is *not* some other kind of task in the job. He can only state what kinds of tasks the test does test.

Process Independence. Each test item must measure only whether the job product is produced or not. This measure must be independent of the *process* for producing that product. This means the test can be used to evaluate alternative processes; e.g., different documentation or training for the job.

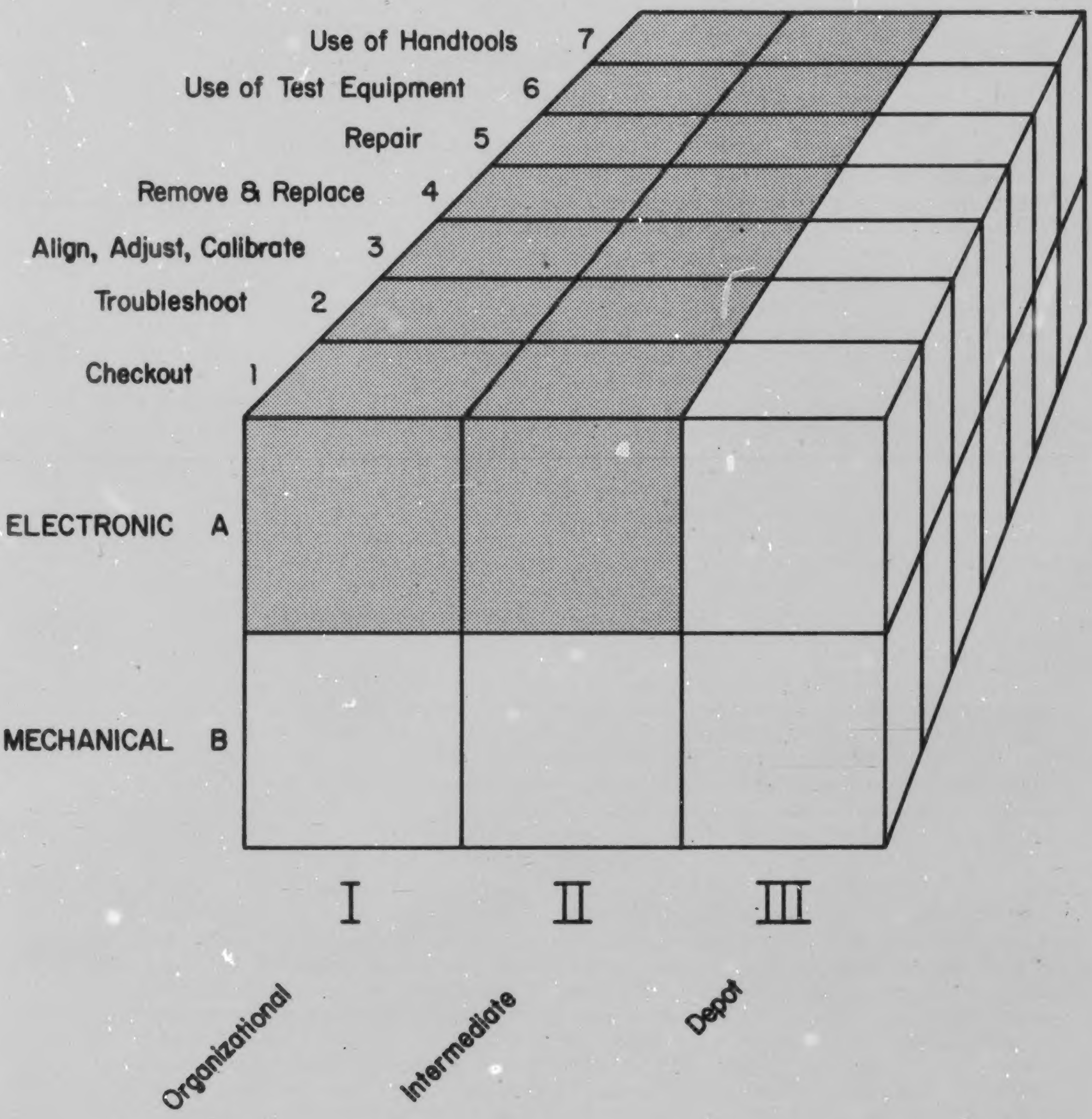
Diagnostics. Since the test does not measure or give scores for steps in the performance process, it provides no formal indication of "why" a test subject failed to produce a particular job product. But the test can be designed to provide *supplementary* information for such diagnostic purposes. Furthermore, these diagnostics may be organized into a formal framework of dependencies to be organized into subtests. For instance, a subtest on "special tool use" should be administered before personnel are tested on job products that require "special tools" for their products. Since production of job products is dependent on use of special tools, no useful purpose is served by testing personnel on job products until it is determined that they can use the special tools. However, this diagnostic framework is based on *assumptions* made for efficiency in testing. The ultimate criterion is always production of job products and subtests can only be referenced to that criterion.

Administrative Feasibility. The test situation must be such as to allow the test subject to produce the job product or a product that is *tantamount* to that. This imposes a considerable administrative effort, far greater, for instance, than would be required for a paper and pencil test of job knowledges *assumed* to be prerequisites for the job. But to make the administration of a criterion reference test feasible there may be need to separate the main test into a series of subtests referenced to the job products. Careful though and analyses should go into all the administrative details for maximizing the number of personnel tested in a given period of time.

Standardization of Test Conditions. Test conditions should be standardized *except* for the treatment under test. For instance, if the treatment of subjects being tested is use of different documentation, than all other conditions should be standardized; e.g., hand-tools, location of spares or lubricants, test equipment, etc. This does not mean that multiple treatments cannot be tested at the same time; e.g., documentation *and* training, but then the results cannot be traced to one treatment or the other, but must be attributed to whatever was allowed to vary.

Scope of Coverage

The tasks that maintenance men perform for the Air Force are many and varied. A convenient model for indicating and classifying this wide variety of activities is presented in Figure 1. The various types of maintenance activities (such as, checkout procedures; align, adjust and calibrate procedures; troubleshooting; remove and replace procedures; and the use of tools and test equipment) are represented on one axis of the model. Since mechanical equipment and electronic equipment usually require a different variety of maintenance actions, they are represented by another axis. The third axis of the model represents the three levels or categories of maintenance now found in the military services. Organizational maintenance is the first level. It is usually aimed at checking out a whole machine subsystem and correcting any identified faults as quickly as possible. Flight line maintenance falls in this category. A system is checked out. If it does not work, the line replaceable unit (LRU) or "black box" causing the malfunction is identified and



A Functional Representation of the AF Maintenance Structure

Use of Handtools 7
Use of Test Equipment 6
Repair 5
Remove & Replace 4
Align, Adjust, Calibrate 3
Troubleshoot 2
Checkout 1
ELECTRONIC A
MECHANICAL B
I
II
III
Organizational
Intermediate
Depot

Figure 1. Job Task Performance Tests.

replaced. This major component is then taken to the field shop (intermediate maintenance) where it is again checked out and the faults, authorized for correction, are corrected. The corrective actions, authorized at the intermediate level, vary greatly from system to system depending on the maintenance concept of each system. On some systems the maintenance man will troubleshoot the "black box" to the piece part level. In more modern equipment, he will identify a replaceable module made up of many piece parts. Some modules are thrown away, others sent to the depot for repair. Any line replaceable units which the field shop are unable, or unauthorized to repair are sent to the depot for overhaul.

Organizational and intermediate level organizations are manned primarily by enlisted technicians whose average length of service is rather short (slightly more than 4 years in the Air Force). Depots are manned largely by civilian personnel with a much higher level of experience and longer retention time. Using this model it has been possible to specify areas of concentration for study.

The scope of this test development effort includes the shaded cells of the model. The actual tests were to be developed for the intermediate level of maintenance but all of the job activities of the organizational level of maintenance are included in the intermediate level. The only difference is that these common job activities are usually performed in a different job environment. (For example, for organizational maintenance on aircraft these common tasks are performed on the flight line while for intermediate maintenance they are performed in the field shop.)

The AN/APN-147-AN/ASN-35 system was used as a test bed for the application of the model. To broaden the coverage would be to reduce the practicality of the model for implementation, and restrict it to an abstract level of conceptual thinking and discussion. The type of tests described here can be used by supervisors or standardization teams to test the job capability of personnel at any level of maintenance. But more importantly, the tests can be used to measure the effectiveness of any job processes, job aids, or job training, because they are process independent.

The intention of this effort was to add to the concept of criterion referenced JTPT by specifics generated through implementation and practice. The authors do not know how far the specifics can be stretched to become generalities. But, a reasonable assumption is that the tests in the battery which has been developed can serve as models for tests for measuring the effectiveness of maintenance on other electronic hardware.

Approach

During the course of this project an approach to criterion referenced JTPT and scoring scheme development evolved that appears to be a valid general model, at least for classes of maintenance outlined previously.

Main Elements of Approach

The main elements for implementing this approach are as follows:

The **first step** *is to identify the major classes or kinds of tasks that are involved in the job or skill area under consideration*. For this project, these classes have been initially identified in AFHRL-TR-74-57(I) and are discussed above under Scope of Coverage. They include equipment check-out, alignment/adjustment, component replacement, fault isolation, test equipment usage, and hand tool usage. These classes served as the *representative kinds* of tasks required by the job. During the development process and test try-outs, certain shifts in emphasis and definition became necessary.

The **second step** *is to define and describe the input, processing and output conditions for each of the kinds of tasks established in Step One*. The output requirements were stated in terms of the specifications of the output *products* in each class of tasks. In electronic maintenance the product is always an item of equipment repaired and ready for field use. To produce this product the test subject must perform certain processes on the inputs to him. Even though the *process* which the test subject uses is not measured directly in the criterion referenced JTPT, it is still the performance process that is of interest to us. For instance, a given unit which has been repaired represents one product. But it can fail in many ways, each of which requires a certain repair process. After any repair the product is the same, a unit ready for field use. But we are interested in the performance process. We measure its accomplishment by the product. But we want to know if the test subject can fix the equipment regardless of its input condition. The input conditions should be those common to the job but standardized for the test.

It is also important to consider the performance processes in order to make *diagnoses* from the test performances, that is, to help answer questions about *why* the subject does not produce a criterion output as the result of his performance process. By analyzing and defining the process in general terms, such diagnostic categories as "test equipment" or "hand tools" can be identified as potential ar[illegible]f weakness in electronic maintenance. That is, a common cause of failure to produce criterion outputs may be traceable to an inability to produce the proper outputs on test equipment or from the improper use of hand tools. These common causes are themselves candidates for subtests. That is, subtests can be established for "use of test instruments" or other "sub-routines" in the performance process for the whole job. Any common causes of difficulty should have tests constructed for them. And personnel should be able to perform correctly on those tests before taking a test for the whole job.

The **third step** *is to select certain job products or job processes in each kind of job duty for the test.* In some jobs it may be possible to test *all* the job products in one kind of job duty. But that is not always administratively feasible, and in the present case of electronic technicians it certainly is not. In the case of an electronic technician the "job products" of troubleshooting are at least as large in number as the number of parts in the equipment because a different job process is involved in repairing each part. There is a question of "how many" or "what percentage" of the total number of job processes or outputs will constitute a "representative" sample. There is no absolute answer to this question.

Whatever answer is arrived at, short of testing 100% of the job products, is subject to challenge. It can be argued that one process or output *not* tested out of a thousand tested would *not* show the same results as the others. Admittedly, objecting to one process out of a thousand is a feeble argument. A job supervisor would be happy to get and electronic technician who could solve a thousand problems, but be of doubtful ability on only one. In fact, a job supervisor might be happy to get a man who could solve only half the problems in the equipment. This example is given to show that "representativeness" is not just a theoretical question, but a practical one. In a practical sense, the question may reduce to one of specifying to the job supervisor what percentage of the job outputs the test subject has been tested on and let him say whether he would be satisfied with a man of proven ability on that job sample. The ultimate question of "representativeness" comes down to such practical considerations. But there are other actions to be taken to improve representativeness in the test.

In second step the *processes* of producing job products were examined. This provides the test constructor with an idea of further subdivisions within a given kind of job area. For instance, in the category of "alignment" several different processes might be found. One alignment might be identified which requires disassembly of many parts and another that requires none. This indicates somewhat different processes involved in the performance of each. The test should include some products from each of these categories.

In developing the present model test, the adjustment/alignment/calibrate category had 40 job products. The troubleshooting category had thousands of job products (one for each part). The equipment was subdivided into electronic stages, and one job product selected from each stage to gain representativeness. But representativeness cannot be guaranteed. After taking a battery of criterion referenced JTPT we can say quite accurately what tasks the test subject *can* do, but we can't go beyond that. It is essentially up to the user to accept or reject such a person.

Figure 2 presents a flow-chart type representation of the relationship among the kinds of tasks for electronic jobs. The solid lines indicate the series of relationships found to be the most common pattern of technicians' actions. The dotted lines indicate possible but less likely relationships.

The **fourth step** *is to construct a framework of subtests referenced to the main criteria. This is done for efficiency in testing, not for theoretical reasons.* In fact, theoretically it is undesirable. It would be desirable to test each person on a full scale of criterion referenced tests, covering every possible task of his job, then there would be no question of the relevance of the performance required. But for *practical* reasons the subtests are introduced to make the administration of the tests feasible. The framework of subtests is a *rational* one, but the reasoning on which it is based is always *subject* to some question.

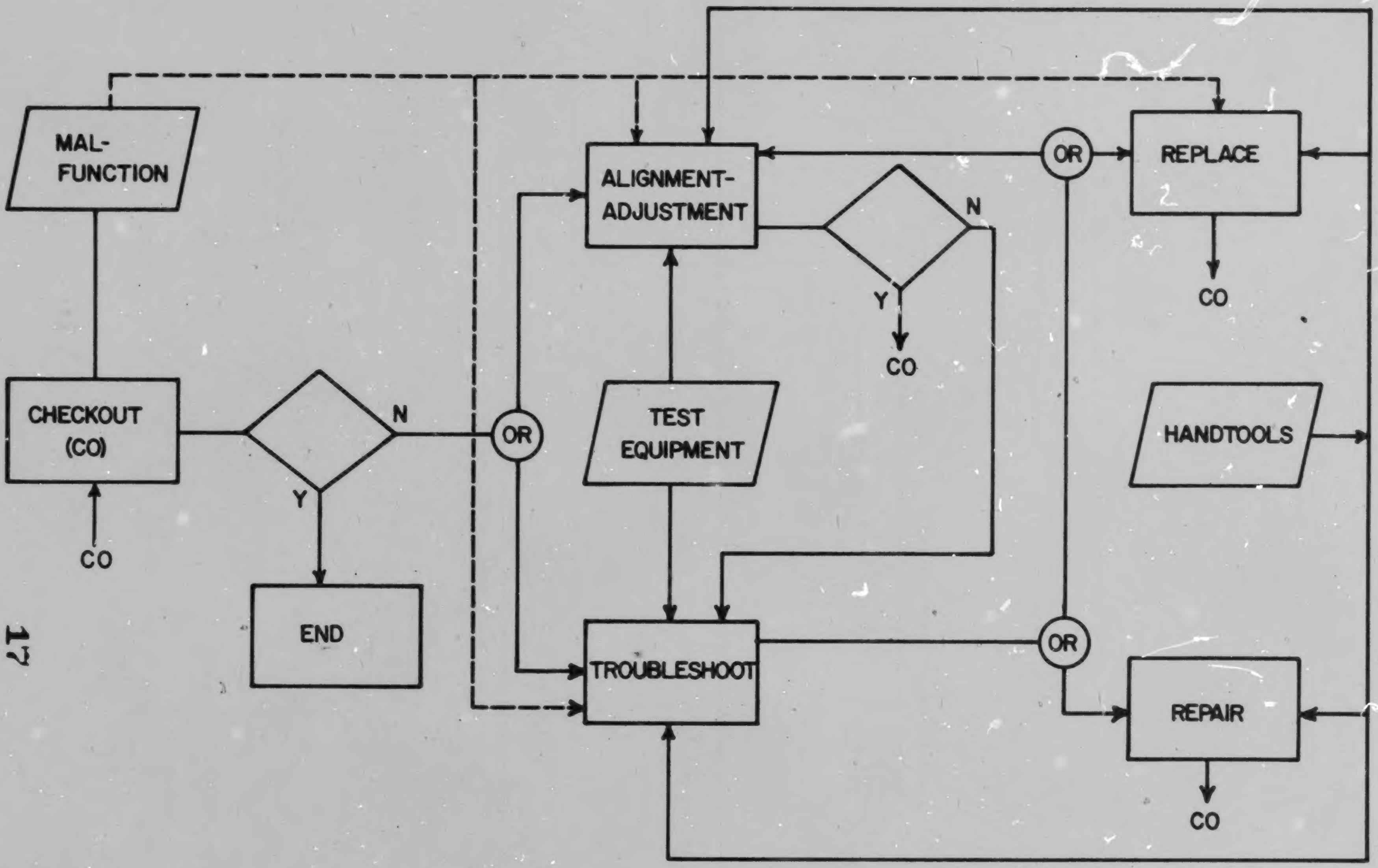

MAL-FUNCTION
CHECKOUT (CO)
CO
Y
N
END
OR
ALIGNMENT-ADJUSTMENT
TEST EQUIPMENT
TROUBLESHOOT
Y
N
CO
OR
OR
REPLACE
CO
HANDTOOLS
REPAIR
CO

Figure 2. Electronic maintenance task relationships.

However, with the criterion reference available, the questions can always be answered. If a representative group of men fail on a subtest but can produce the job products in a full scale of criterion referenced tests, the reasoning or assumptions on which the subtest are based are incorrect and the subtest must be revised or eliminated. So there is a "fail safe" feature to subtests which are referenced to the job criterion.

The framework is constructed on the basis of *assumed dependencies*. Table 1 presents a structure for considering this rationale of dependencies. This table indicates that troubleshooting is the most complex and demanding task. Within the concept of troubleshooting is included not only fault isolation but also the necessary activities for returning the equipment to field ready use once a fault is isolated. Within the fault isolation portion of troubleshooting, several types of activities are required. Fault isolation usually requires the use of a checkout procedure to surface "out of tolerance" conditions. It requires the use of some cognitive activity usually structured in terms of some sort of troubleshooting scheme, strategy or logic. But the execution of this scheme requires that the troubleshooter gather information about the operation of the equipment under test. This requires the proper use of test equipment. It makes little difference how good his cognitive scheme for fault isolation is if his improper use of test equipment is feeding him faulty information about the equipment's operation.

If we give a subject a fault to isolate and he fails to isolate it, his lack of ability could be: the result of improper checkout, a faulty cognitive process, *improper* use of test equipment or inability to use hand tools. We have no way of knowing which one from this test alone. But if we have given him subtests on use of test equipment, on use of hand tools and on the checkout procedure and he has demonstrated that he can perform these activities, we can be reasonably sure that his cognitive processes are at fault. If on the other hand such subtests indicate that he cannot use his test equipment properly, there is little to be gained by concentrating on the cognitive processes until his lack of ability to use his test equipment has been corrected.

Once the troubleshooter has isolated the fault he must take the necessary corrective action to return the equipment to field ready condition. This could include align and adjust action, or remove, replace or repair actions including soldering. A weakness in any one or all of the eight activities indicated in Table 1 for troubleshooting could result in the troubleshooter not returning the faulty equipment to field ready condition.

The table also indicates that align and adjust procedures, as well as, remove and replace, repair, and checkout procedures may under certain job conditions be considered independent activities, each in its own right, with its own set of dependencies. The tests and subtest developed during this effort reflect the framework indicated in this table and in Figure 2.

The **fifth step** *is to determine the means for measuring the task output or product that will indicate that the task has been completely and correctly performed*. This is accomplished by inspecting the final product to see if it meets specifications. In practice the test administrator does not *necessarily* have to make a special measurement of his own. As a *practical* matter he can observe the unit check-out results obtained by the test subject in lieu of making the checks himself. But the test should state, for the Test Administrator (TA), what the specifications for each product are (by reference or with a special piece of paper, template, or whatever is necessary). The TA merely scores the test subject as "go" if his product meets *all* specifications or as "no-go" if *any* product specifications are not met.

It should be noted that some products become "sealed units" when they are repaired. In this event the TA must be told to make certain inspections before the unit is "sealed." For instance, a lubricant may be placed in a unit before it is closed up. The test administrator cannot determine whether the correct lubricant has been used, or if any has been used, by inspecting the sealed unit. He must observe the markings on the lubricant container during the performance process to see if specifications have been met. There are other instances in which the easiest and best way to measure the product specifications is to observe some aspect of the performance process. But this performance is not scored as a performance. It is only used as a convenient way of *measuring* part of a product specification.

The **sixth step** *is to determine how to simulate the input and output conditions for the test in the same way they occur on the job*. In the case of mechanical or electronic maintenance the input conditions may occur in several ways. For instance, a supervisor may be part of the input conditions. He might say, "There is a crack in the drive shaft. I want you to take this section out and replace it." Or the same man

Table 1. **The Relationship and Dependencies Among Maintenance Activities**

	Checkout	Troubleshooting Scheme or Logic	Use of Test Equipment	Use of Handtools	Align and Adjust	Remove and Replace	Repair	Soldering
Troubleshooting	⊗	⊗	⊗	⊗	X	⊗	X	X
Align and Adjust	⊗		⊗	⊗	O			
Remove and Replace	⊗		⊗	⊗		O		X
Repair	⊗		⊗	⊗			O	X
Checkout	O		⊗	⊗				

⊗ Indicates that item is almost always a dependency

X Indicates that it may be a dependency

might discover the same crack while lubricating a joint on the drive shaft. Or it might be discovered during a routine inspection. The question for the test developer becomes one of "which condition to simulate." The answer is quite straightforward. It is to state clearly what it is you are simulating in the test. If you want to test the man's ability to remove and replace the driveshaft, start with input conditions that tell him to remove and replace it, just as a supervisor would do on the job. If you want to test his ability to recognize a crack then use input conditions which start with an inspection. The test constructor must state what it is that has been tested, and he must give the specifications for it.

He must *also* use the proper input conditions for the situation he says he is testing. For the test this input condition must be standardized; e.g., the same crack for all test subjects. A hairline crack should not be used for one man and an eighth-inch gash for another. The same thing is true for failure. The cause usually must remain a constant condition of the test so long as it is being used for a particular purpose. In addition to specifying the means for measuring the main job products, subtests also require the *creation* of simulated job products or outputs. For instance, it special test equipment such as an oscilliscope is separated out as a subtest, a "simulated product" may have to be generated for it. By making this a subtest, we have taken away the regular job product: a repaired item of equipment. We must create a replacement product. The replacement should impose the same demands on the test subject, *with respect to the oscilliscope*, that the regular job does. The substitute product should have output specifications similar to the real job product. Also a similar input should be provided.

But the process can be attenuated. An example of this attenuation is as follows: A substitute equipment to be measured by an oscilliscope would be generated. It would produce a signal similar to the real equipment. But it would not require the test subject to find the right place to measure, or even what the measurement should be. It would not require any further processing other than to be measured by an oscilliscope. This greatly attenuates the job process and leaves only the requirement for a measurement by the oscilliscope. This attenuation is a major way in which the administration of the battery of criterion referenced JTPT is simplified and made feasible.

But this item of substitute equipment must give the test subject *no hint* of how to operate his oscilliscope to get the right output from the equipment. The output of this substitute box is known by the TA. The test subject's job is to compare his reading with a reading given him for this substitute equipment and say whether it is good or bad. This is the same thing the job requires. The test should not require the test subject to verbalize or write the output in volts, microseconds, frequency, etc., but only to say good or bad, as the job requires. Examples of such substitute products for subtests are presented later in this volume.

The **seventh step** *is development of the administrative arrangements for the tests*. The decisions regarding criterion test items and their specifications have a direct impact on how the test will be administered. It must be remembered that the (administered) situation for each test item must allow for the test subject to produce a job referenced product or output. Within this condition every effort must be made to make the tests simple to administer. In some cases it may be necessary to reexamine the criterion product in order to devise a more administratively feasible method of evaluating performance.

The primary administrative considerations are cost, time, test security, administrator-test subject ratio, equipment degradation, and administrative instructions. After establishing the administrative details of the test, a final product or output still must be producted *or* the process performed must be *tantamount* to producing the product. An example of a process stopped short of a product which is *considered* tantamount to production of a product is as follows:

A faulty part is inserted in the equipment by the test administrator. The test subject's job is to restore the equipment to field ready condition. He goes through whatever process he chooses to accomplish this. But to achieve the final product the final step in this process is to unsolder the faulty part and solder in a good one (then check to see that this accomplishes the repair). *Administratively* this last step is *undesirable*. *Administratively* it is much more efficient to *stop* the test subject before he unsolders the faulty part. (Soldering and unsoldering places much wear and tear on equipment and, in a test situation, equipment would soon wear out around this faulty part.) Also the equipment with the same faulty part is needed for the "next" test subject. But if we accede to these administrative efficients, we are not producing the product of a field ready item of equipment. In the present tests this dilema was resolved by saying that the identification of the faulty part was *tantamount* to producing the final product. Soldering and unsoldering of parts were tested in a subtest, and it was *assumed* that if the test subject could solder and unsolder parts in a subtest he could do the same in the main test. But this was an assumption. It is open to question at any time. It can be answered by having the test subject *complete* the job product. This option is *always available* in a criterion referenced JTPT. But this does not mean that the option must always be *exercised*. The present writers feel that it is sufficient for the option to exist and the assumption identified as open to challenge. This is the same basis on which a framework of subtests is established. These *concessions* are made to make the tests more administratively feasible and here the matter must rest. The test constructor can resolve the administrative dilemmas any way he chooses. But he must state what he has done so that the ultimate criterion reference is always attainable if sufficient administrative resources are expended to achieve it. It is *not* desirable to make these administrative concessions. To some extent they weaken the strength of the reference to the job criterion. But it is not a bad compromise so long as the reference thread is not lost and can be established to "test the test" at any time.

Other Approach Considerations

The following discussion broadens the issue just introduced to aspects of the electronic maintenance job other than troubleshooting to a faulty part. In performance testing, the equipment damage consideration is a major one for several reasons. *First*, the equipment must operate properly and reliably to permit smooth progress of the test administration. Equipment down time can ruin a testing schedule. *Secondly*, since students will be altering the equipment, there is a possibility of equipment detuning and of test compromise by overworking a given part of the equipment.

Several steps can be taken to overcome these tendencies. **First**, *keep the test subject's equipment alteration requirements to a minimum*. In the troubleshooting portion of the tests developed in this project, test subjects are not permitted to unsolder and connections. A replacement routine is utilized instead. The test subject soldering capability is then tested on work samples which are not part of the prime equipment. When it was not possible to conduct the test without test subject alteration of the equipment, as in alignment or component removal and replacement, detailed instructions and aids were developed for the Test Administrator, so that he could quickly restore equipment to its proper operating condition without the use of sophisticated test equipment.

Second, *test administration procedures and instructions should be set up so that the normal technical supervisor can administer the tests with a minimum of difficulty*. By keeping the administrator requirements for technical expertise to a minimum, the probability that the tests will be properly administered will be increased. Administration instructions must be explicitly detailed and amply supplemented by graphic depictions of equipment test configurations. In addition, Test Administrators should be given practice in administering the tests to become familiar with testing idiosyncrasies.

Tryout and Revision

The **eighth** and **final step** in test development *is tryout and revision*. For performance testing the Test Administrator tryout is as important as the test subject tryout, if not more so. The purposes of the tryout are to ascertain whether the written instructions communicate as intended and to determine the feasibility of test procedures. In this project, several such tryouts were held at various stages of development and proved invaluable in pointing up where instructions were inadequate or confusing and for verifying test procedure feasibility. Such trials, of course, are much more meaningful if the samples of test subjects and administrators approximate the ultimate target population.

Summary of Steps for JTPT Development

1. Identify major classes of job tasks.
2. Define and describe each class of tasks in terms of inputs, outputs, and processing conditions.
3. Select a representative sample of job products or processes to be measured.
4. Construct a frame work of subtests referenced to the main criteria.
5. Specify standards by which to evaluate output.
6. Simulate input and output conditions in job-like ways.

7. Develop the administrative arrangements for the tests.

8. Try out and revise the tests.

Relation to Previous Efforts

Performance tests are not new in the Air Force. Many have been developed on an ad hoc basis for use in research concerning training. During and after World War II the Air Training Command used elaborate and comprehensive check rooms in their technical schools. Some of these operations still exist on a modest scale. What is new is the systematic approach for developing JTPT, the results of which will be more meaningful in terms of demonstrated performance of typical job tasks. Important aspects of this approach include the following:

1. A more precise description or definition of a job criterion in terms of job products has been used consistently throughout the tests. This criterion of specified job products is used (criterion referenced) rather than stating that some percentage of the total number of necessary performance steps in the production process is correct (norm reference). This is the essential difference between a criterion referenced test and a norm referenced test.

2. But beyond that, the present study is intended to describe systematic ways of dealing with the many types of activities that are contained within a single job. This is done through a classification of maintenance activities and a framework of subtests referenced to a single criterion of producing field ready equipment. Electronic and mechanical maintenance jobs have the characteristics of many types of tasks within one job. To treat them, the concept of criterion referenced testing had to be extended in some way. This is a report of one way in which it was done in a manner making such tests administratively feasible.

3. Each type of job activity has been considered separately for the purpose of test development and scoring. A number of tests have been developed for each type of job activity.

4. Since the factors being measured are so complex and diverse, the result of each test is reported separately. No attempt has been made to report test results in terms of a meaningless single score for an individual.

SECTION II. TEST DEVELOPMENT

Introduction

As stated previously, the prime equipment selected for this project was the AN/APN-147 Doppler Navigational Radar and its associated AN/ASN-35 Computer. This equipment is standard on several operational aircraft and its maintenance is fairly complex. Responsibility for its maintenance is assigned to personnel with Air Force Specialty Code (AFSC) 328X4, Avionics Inertial and Radar Navigation Systems Technician. This AFSC is also responsible for many other electronic systems, and an individual in this AFSC may or may not be exposed to all of these systems during his time as a technician. The intermediate level of maintenance was the primary concern of this project. Most organizational activities also are included in intermediate maintenance activities. As a result, tests for organizational maintenance can be readily developed using the tests developed for this project as models.

Throughout the development of all of these criterion referenced JTPT, the steps outlined in Section I were followed. The following discussions concentrate on the peculiar problems that were associated with the development of each type of test.

Troubleshooting

The objective of the troubleshooting process is to isolate the faulty component and to return the equipment to a field ready condition. The first step taken was to identify the range of equipment faults that could occur by analysis of the equipment. This was done by identifying from the equipment schematics all of the "functional elements" or "stages" of the system. Then a piece part from each stage was identified as a candidate for fault insertion. These parts were selected so as to provide a basis for development of both "within-stage" and "between stage" troubleshooting tests, since both types of troubleshooting are required at the intermediate level of maintenance. Figure 3 lists the functional elements, references the schematic from Technical Order (TO) 12P5-2APN147-2, and identifies the part selected for faulting, along with its identification from the TO.

These tests are administered at a normal work station where all of their usual job aids, such as references, test equipment and hand tools, are available. The test subject is told the equipment is malfunctioning and is given several symptoms of the type that would normally be on the tag when the equipment comes into the shop from the aircraft. The test subject is instructed to isolate and identify the faulty component. He is told that he may use any procedures, references, or test equipment which he chooses. (None are suggested, recommended, or graded). To this point the test situation exactly duplicated the job situation. However, at this point there is a deviation to increase administrative feasibility. The test subject is instructed *not* to unsolder any parts in the equipment. He is told that any time he wants to replace a suspected component he is to remove the module containing that part and request a module from the TA which contains a replacement for the specified part. The TA will take the module and, if the replacement part requested by the test subject was *in fact* the faulty one inserted into the equipment, a good module is returned to the student. If the replacement part requested by the test subject is not the faulty one, the TA, after a standard delay, will return the module to the subject indicating that the suspected component has been replaced.

After the exchange, the test subject has to replace the module and determine whether the fault has been found (checkout). When the test subject performs the checkout and is satisfied that he has found the trouble, he lists the faulty part on his answer sheet and turns it in. That completes the test. His answer sheet can then be graded on the basis of right or wrong on a measure that is tantamount to producing the final *product*.

To provide additional diagnostic information about each test subject's performance, the Test Administrator will record each part that the subject requested and the subject will indicate what test equipment he utilized. In this way, a complete record of the individual's troubleshooting strategy will be available. This information on process may be of interest, but in terms of scoring, only the faulty part listed by the test subject on his answer sheet will be graded. The test subject identifies the faulty part or he doesn't (go, no-go). (A detailed description of all graded items is included in Section III.)

While this "module exchange" technique represents a difference from the job situation, incorrect estimates of the problem still penalize the test subject by requiring him to remove a module, present it to the TA, describe the suspected malfunctioning part, install the replacement module, and check it out. This process will generally be equal to or slightly less than the time normally spent by the technician in unsoldering, testing, removing, acquiring a replacement from supply room, and installing a new component. While the activities are some what different from the actual troubleshooting activities, they do not promote or reward significantly a typical behavior on the part of the technician (e.g., random trial and error searching does not have either a higher payoff or lesser penalities than in the actual job situation).

Time to Perform

The amount of time required to correct the equipment and bring it to field ready status is a function of a number of factors. There is some theoretical minimum time required to perform each process. But like a "four minute mile," the absolute minimum time is never known for certain in practice. The theoretical minimum time required for accomplishing each process in the test could be estimated. For instance, a technician might be rehearsed on a procedure for a day or so and then timed with a stop watch. But there is a question of what this would mean in terms of job standards. In electronic and mechanical maintenance jobs, there are no exact time standards on the job. There are estimates of what is "reasonable." But in the field shop job incumbents are not usually held to strict accountability for performing within these times. (Time to perform on the flight line at times is more critical than in the shop).

So for these tests there were approximations made of how much time each process would require. This time was "tried out" in pretrials, rounded off to quarter hour increments and used. The final time limits on each test item represent an amount of time that a supervisor would "not complain about" if a job

	Schematic	Part Number
(1)	Frequency Tracker Power Supply (Fig. 8-36)	V-07 (6080WA)
(2)	Frequency Tracker Power Supply (Fig. 8-36)	CR-03 (IN256)
(3)	Modulator (Fig. 7-15)	Q-07 (2N491)
(4)	Modulator (Fig. 7-15)	R-34 (27K)
(5)	Modulator (Fig. 7-15)	C-03 (4700PF)
(6)	Modulator (Fig. 7-15)	L-01
(7)	Modulator (Fig. 7-15)	C-27 (82PF)
(8)	IF Amplifier (Fig. 7-17)	V-01A (5670)
(9)	IF Amplifier (Fig. 7-17)	R-08 (5.6K)
(10)	IF Amplifier (Fig. 7-17)	CR-01 (IN277)
(11)	Electronic Control Amplifier (Fig. 8-30)	R-37 (10K)
(12)	Electronic Control Amplifier (Fig. 8-30)	V-02 (5670)
(13)	Electronic Control Amplifier (Fig. 8-30)	R-26 (470K)
(14)	Electronic Control Amplifier (Fig. 8-30)	CR-01 (IN756)
(15)	Signal Comparator (Fig. 8-28)	V-02 (5725)
(16)	Signal Comparator (Fig. 8-28)	C-14 (.047uf)
(17)	Signal Comparator (Fig. 8-28)	R-21 (120K)
(18)	Frequency Mixer (Fig. 8-26)	V-01 (5670)
(19)	Frequency Mixer (Fig. 8-26)	C-15 (6000PF)
(20)	Frequency Mixer (Fig. 8-26)	K-01
(21)	Relay Chassis Assembly (Fig. 7-45)	CR-24 (1N2070)
(22)	PNP Multiar & F/F Board Assembly	Q-04 (2N502A)

Figure 3. **Functional components faulted.**

incumbent took that amount of time to perform that task on the job. It is a great administrative convenience to have set amounts of time for eact item. But the time limits should be set so that test subjects failed because they didn't know how to perform, not because they weren't fast enough.

The question of using time as a measure of performance effectiveness could be argued. That is, it could be argued that a man who performs in less time than another man is "better." Time to perform is an important norm referenced concept: to compare times for individuals in training required to reach the "go" criteria on the various criterion referenced tests may become an important factor for the standardization of selection tests. But time is not germane to the criterion referenced aspects of criterion reference tests as defined here – that is, the *product* which the test subject generates. Generally, individuals are not rated precisely on their speed of performance of maintenance activities on the job. To repeat, the time limits set for each test item is a time that supervisors would accept as OK.

Prompting

No "promptings" are allowed in the test. The TA is under strict instructions not to help or prompt a test subject. There is no way to standardize these "prompts." One type of prompt may make the difference between accomplishing the product or not. Another may save the test subject a minute or so and still another "prompt" may interfere with the test subject. So it is of little value to count the number of prompts, as they do not have an equal effect on test subjects. It is true that a man might receive a "prompt" on the job, particularly if he asked for help. But in such a case the man is not actually performing the whole task on his own, he is receiving help. Each performance test is designed to ascertain whether the test subject can perform the task on his own, not how well the TA can perform the task. And finally, when TAs are allowed to give help, they have been known to virtually "take over" from the test subject and do the job themselves. This array of reasons against promptings makes it very clear that TA must be strictly prohibited from prompting test subjects. Experience from this project indicates that TAs *can* be prohibited from this kind of interference with the test, but it does require stern admonitions, sometimes multiple.

This is not to say that a TA cannot derive *diagnostic* information from observing a test subject's performance. That is, even if he is prohibited from prompting the test subject, the TA can still try to diagnose why the test subject gets "hung up" at certain points. (It is the opinion of the authors that the diagnostic nature of the subtests is much more useful than the diagnoses of a TA made during a test. A formal record of inadequacies on subtests is felt to be more useful to a training operation than are the fleeting impressions and hypotheses of a TA. This is not to say that the TA can't develop some judgements based on test results.)

Application of Rationale

With this general testing rationale developed and with the equipment functional components defined, it was then possible to develop a series of troubleshooting tests that represent within and between stage troubleshooting for the AN/APN-147-AN/ASN-35 system. Several sample tests were prepared along with the necessary test administration instructions and both were tried out on a group of technicians. This administration demonstrated that the component exchange rationale was feasible and easily handled by both the student and the TA. The ground rules concerning time to perform and prompting also were applied to the development of the later criterion referenced JTPT.

It was also discovered that test subjects tended to go first into an alignment/adjustment routine when presented with an inoperative set of equipment. Since these skills were to be tested separately and since, for purposes of the troubleshooting tests, no random adjustments of the equipment could be permitted, a specific instruction was added to each test stating that the test problem was not a function of a misalignment.

Alignment/Adjustment/Calibration

Equipment calibration is a major task of the electronic technician. This task is variously called "alignment" and/or "adjustment." An initial attempt was made to differentiate between these terms for purposes of test rationale development. Adjustment is generally taken to mean manipulating controls to bring a series of equipment parameters into alignment. However, since alignment checking also requires control manipulation, it was found that no meaningful and consistent difference exists between them for testing purposes. Therefore, the same testing rationale was applied to both. The test categories "alignment" and "adjustment," then, reflect only the terms applied to these activities by the official TO.

To discover the nature of the alignment task, (i.e., inputs, outputs, processing), the procedures described in the TO for this equipment were exercised and analyzed. In attempting to carryout the alignment and adjustment procedures for the AN/APN-147-AN/ASN-35 system, it was found that the TO for these procedures could not be followed in all cases. If a technician attempted to follow some procedures, he would not be able to accomplish the task. This poses a problem for the test constructor because he has no way to correct the TO in a formal authorized way in the time available for test construction. So he should avoid such problems by selecting other items for his test. But in some cases, like the present one, this was not possible. One particular procedure was a very common one for the check out of many equipment repairs, so it was included in the test battery.

In this case the local solution was accepted as correct for the purposes of the test. This meant that input conditions for the test were established in accordance with the local procedure. The special test jigs were included as part of the standard equipment provided the test subject. He could use them or not as he chose. The *criterion* was correctly adjusted or aligned equipment regardless of what process the test subject used to achieve it.

It is necessary to have measurement criteria which can be applied consistently from installation to installation, and person to person. Therefore, ***alignment items were selected that give constant values and can be set and unset by TA without going through complicated adjustment procedures themselves.*** This requirement for administrative simplicity eliminated some alignment items from inclusion in the test. But the few excluded items turned out to be some of the rarely performed alignment procedures. This trade-off was considered acceptable to simplify the test administratively.

The testing approach developed was administered as follows: The TA sets up the problem by misadjusting a specified parameter. The Test Administrator's Handbook [AFHRL-TR-74-57(II), Part II] includes instructions to the TA regarding the specific control to adjust and provides him with pictures of precisely where each control is located. The test subject's instructions then tell him to check a specific alignment (e.g., "Lock-Check Alignment" or "Frequency Modulator Adjustment") and to adjust it if required. He then must demonstrate to the TA that the parameter has been adjusted to within tolerance limits. He does this by obtaining the required value on an appropriate item of test equipment and having the TA check it. This is the criterion output measured by the TA. The TA completes an evaluation sheet to indicate whether or not the test subject successfully (go, no-go) performed that alignment according to specifications. The test subject completes a sheet of diagnostic information on which he indicates what equipment he utilized in performing the alignment. This information is part of the diagnosis of his performance process, but not part of his score.

Whenever test subjects are required to make adjustments or alignments, some subjects are going to make "over" adjustments resulting in badly misaligned equipment. The TA should be able to quickly realign the equipment. Therefore, in addition to the graphics and value descriptions for measuring the criterion output, a series of plastic adjustment templates or guides were developed. With these key guides the TA can quickly bring a set back to within acceptable operating conditions for test purposes. These templates are unique to a given type of equipment, but such aids can be constructed for any equipment. It was found during the test that the aids would work properly on all equipments used in the test though it had been anticipated that they might be unique to a given set of equipment. (Such aids could be considered for use on the job, but that is beyond the scope of the present project.)

When subjected to preliminary tryout, these procedures proved to discriminate very well between individuals who could and could not perform specified alighments.

Tests on Use of Test Equipment

An examination of Table 1 indicates that the use of test equipment is an important common subactivity of all product producing activities. What the table does not show is that there are generally two categories of test equipment – special test equipments that are specific to a certain prime equipment such as the AN/APN-147 and the AN/ASN-35 and general test equipments that may be used with the AN/APN-147 and the AN/ASN-35 as well as with many other prime equipments. At the intermediate level of maintenance for the AN/APN-147 and AN/ASN-35, as it is currently structured, the following seven test equipments are required:

1. Tektronics Oscilloscope, Model 545B
2. Voltohmeter, PSM-6
3. Transistor Checker, Model 1890M
4. Electron Tube Test Set, Model TV-2
5. Audio Oscillator, TS-382
6. Signal Generator, AN/URM-25D
7. Doppler Generator, CMA-546A

Of these seven test equipments, only one, the Doppler Generator, CMA-546A, is specific to the AN/APN-147 and AN/ASN-35. The AN/ASN-35 and AN/APN-147 equipment has the characteristic that it must be stimulated by this *special* generator and have special procedures performed on it in order to obtain outputs from it. The others are six general items of test equipment which are used for testing many items of prime equipment. The developmental considerations for each test equipment subtest constructed for this effort are discussed below.

Oscilloscope Test

The oscilloscope has a wide variety of features and capabilities: more than are needed in most jobs, including the present one. A special input simulator (waveform generator) was constructed to serve in place of the prime equipment for this subtest. It required the same type of output measurements as did the prime equipment. Therefore, test subjects used those features of the scope which the prime equipment required to obtain diagnostic information.

This waveform generator was designed to produce a variety of waveforms on the scope. A schematic of this generator is shown in Figure 4. The components were then enclosed in a box and a dummy circuit (Figure 5) depicted on the cover of the box, integrating the leads from the circuit inside. This was done so that accomplished technicians could not solve the problems by inspection of the simple circuit inside.

A series of equipment outputs was then defined which the test subject has to obtain on the scope. Each of these outputs is the waveform present at a specified test point. He must then compare the waveform obtained on the scope with the one drawn on the answer sheet for that item and indicate whether the two are within specified tolerances of each other. The waveform obtainable at any given test point is, of course, constant. By varying the standard given on the answer sheet, however, the answers to different forms of the same problem can be varied. This is a substantial gain in administrative feasibility.

The test subject also recorded certain control settings used in the problem. He must have properly adjusted the equipment and properly evaluated the value of the resultant waveform to get a "go" rather than a "no-go." To disguise the critical control settings, several extra settings are required to be recorded. These are not evaluated in the scoring. The test subject's answers, then, are recorded on paper and can be processed immediately or later.

The test probe calibration is an operation which the TA must evaluate separately. This is necessary to insure that the probe was calibrated before each test subject started his test. It was included as the first problem for administrative convenience.

Several tryouts of this test were required to debug the instructions associated with the test. These instructions were more complicated than those required in other tests and it was also difficult to find personnel sufficiently familiar with the scope operation to apply the instructions. *This provides evidence that training in the practical use of the scope should be improved and that the present subtest would be a useful one in electronic technician training programs.*

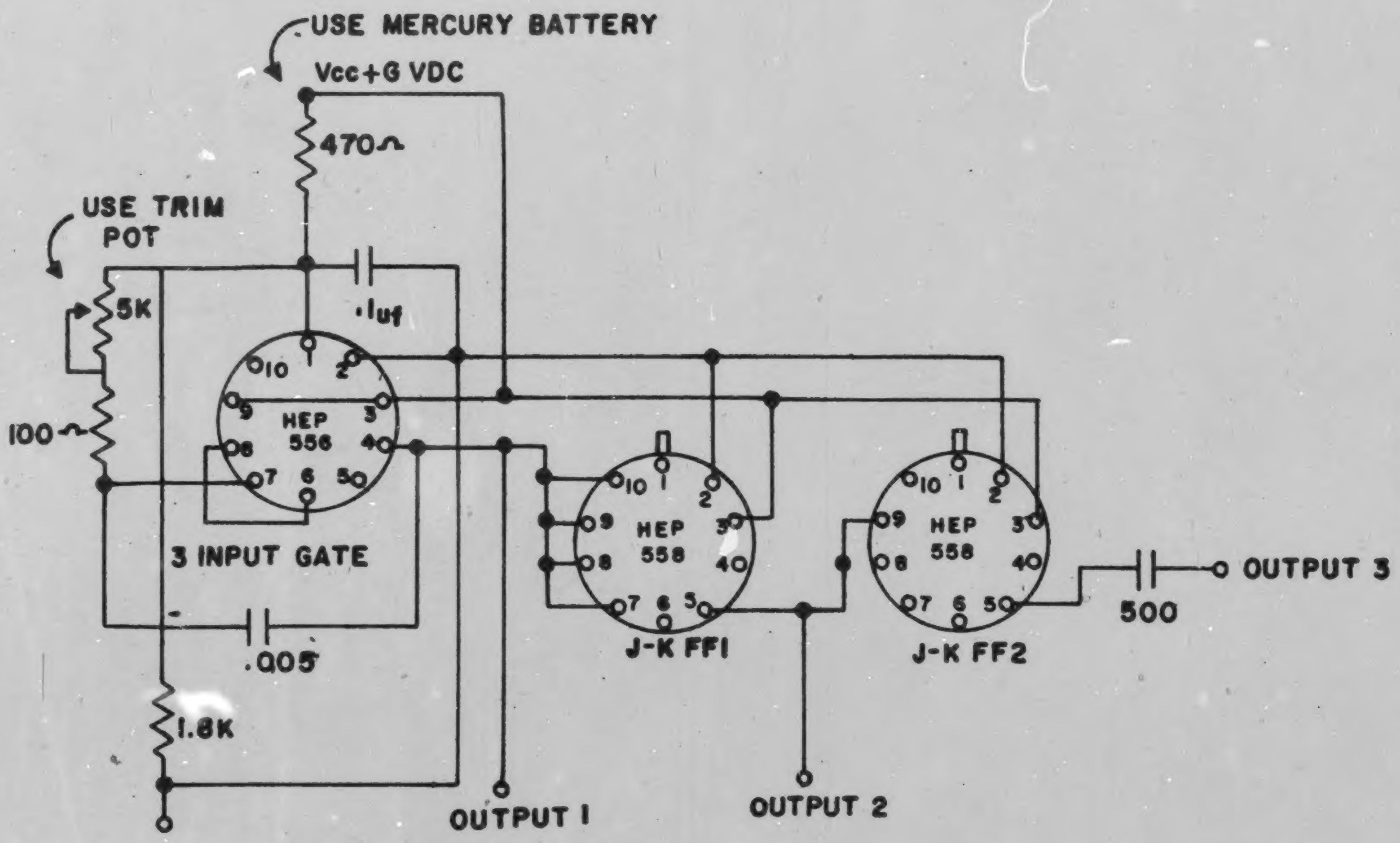

USE MERCURY BATTERY
Vcc+G VDC
470 Ω
USE TRIM POT
5K
100 Ω
.1uf
HEP 556
3 INPUT GATE
.005
1.8K
OUTPUT 1
HEP 558
J-K FF1
OUTPUT 2
HEP 558
J-K FF2
500
OUTPUT 3

Figure 4. **Schematic diagram waveform generator console.**

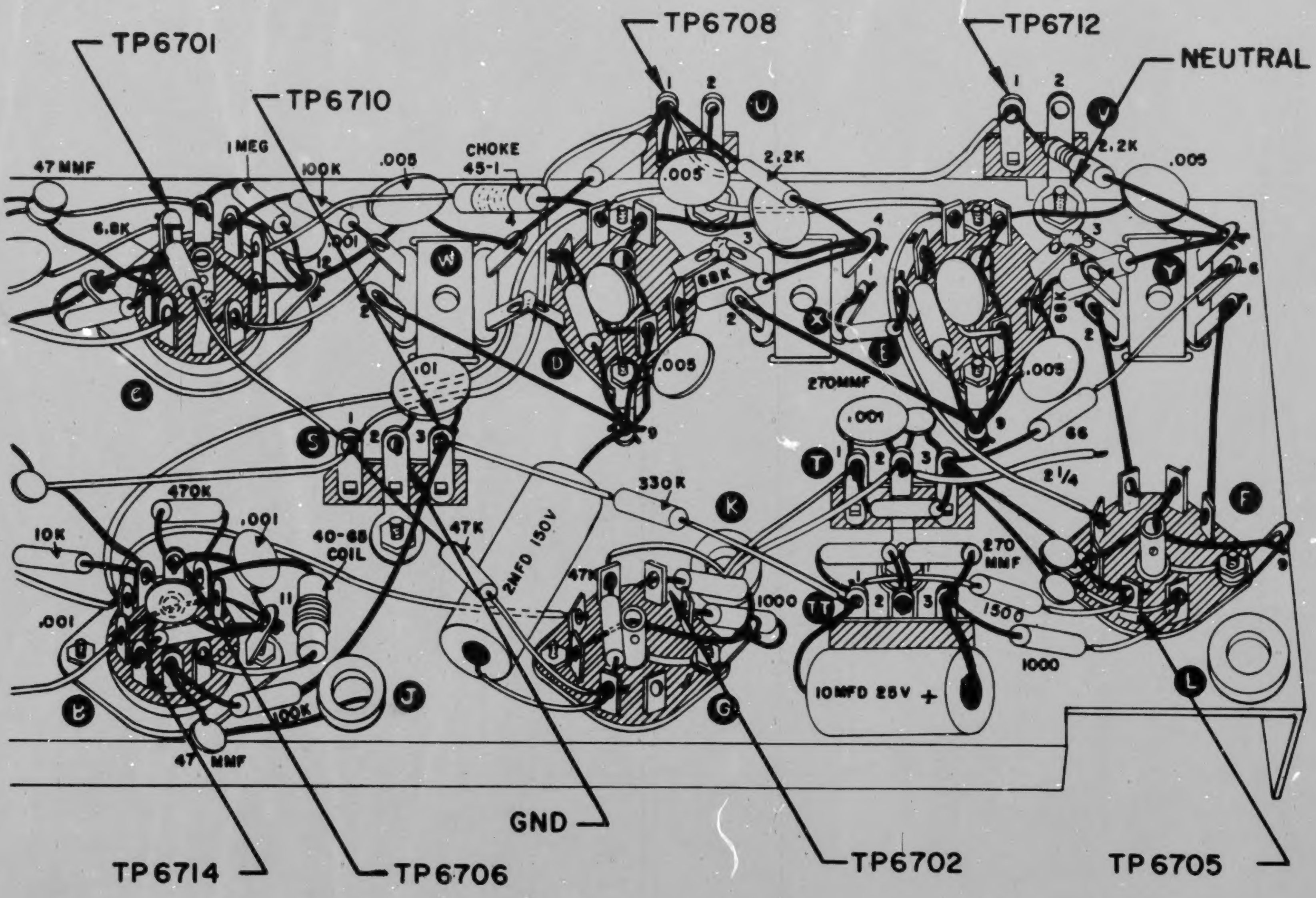

TP6701
TP6710
TP6708
TP6712
NEUTRAL
47 MMF
1 MEG
100K
.005
CHOKE 45-1
6.8K
.001
12
2
W
D
U
2.2K
.005
4
3
68K
X
E
V
Y
6
1
C
.101
S
1
2
3
9
270MMF
.001
T
66
2 1/4
F
470K
10K
.001
40-68 COIL
11
47K
2MFD 150V
330K
K
1000
TT
270 MMF
1500
1000
10MFD 25V +
L
J
47 MMF
G
GND
TP6714
TP6706
TP6702
TP 6705

Figure 5. Waveform generator console.

Voltohmmeter Test

The primary skills associated with voltohmmeter usage are voltage range settings, meter reading, and knowledge of where to apply it on the equipment. The last named skill was not included in this particular subtest because it is part of each troubleshooting test.

To provide a standard test environment, a voltage generator was constructed to give a variety of AC and DC outputs. The different voltage outputs and resistance values are achieved by turning the selector switch to specified positions. The test subject's answer sheet lists specified value tolerances for each position. The test subject must measure the existing value at that position and indicate whether he found it to be in or out of tolerance. This permits, as in the oscilloscope test, the development of alternate test forms. A schematic of the AC/DC voltage generator is displayed in Figure 6. The test box in which it is enclosed is displayed in Figure 7.

Transistor Checker Test

The 1890M Transistor Checker is an in-circuit testing device that permits the testing of a transistor without removing it from the circuit. To provide a suitable subtest, a printed circuit board was utilized that included a variety of transistors. Since the 1890M provides a wide range of measures, the subject is required to make a series of measurements on several test transistors and to record both the parameter values found and whether the transistor is good or bad. This provides an evaluation of the test subject's ability to employ all of the features of the 1890M. Alternate forms of the test were developed by varying the transistors to be tested. It might be noted that this subtest does not require the test subject to use this equipment in the tests. It merely measures his ability to use it.

Electron Tube Test Set, Model TV-2

The TV-2 checks a number of parameters of vacuum tubes, as the 1890M does for transistors. However, the TV-2 checks tubes on an out-of-circuit basis. The test subject is required to record a series of tube parameter values for several specific tubes and also indicate whether the tube is good or bad. Alternate test forms are provided by varying the tubes provided.

Audio Oscillator, TS-382

The audio oscillator is a frequently used item of test equipment. It is used to generate standard signals for input into a system for alignment purposes. The technician must be able to use this piece of equipment to perform various adjustments on the AN/APN-147 system.

To test the test subject capability to use the device, he is told to set up for a specified equipment alignment. He is further instructed that he *must* utilize the TS-382 in this alignment process. This and the criterion measure are the only difference between this test and the corresponding alignment test. When he has the equipment set up and operating, the test subject must demonstrate to the TA that he is getting the proper value reading at a specified point on the prime equipment. This indicates that the TS-382 has been properly connected and adjusted. The TA then completes an evaluation sheet to indicate whether the test subject was successful or unsuccessful.

Signal Generator, AN/URM-25D

This equipment performs the same type of function as the audio oscillator except it generates signals in the RF range rather than in the audio range. The same testing approach is used as in the audio oscillator test.

Doppler Generator, CMA-546A

The doppler generator is used only with the AN/APN-147 and drives the equipment for a specific operational check. To test the subject's ability to employ this test equipment item, he is instructed to set it up and to demonstrate its use to the TA. The TA in turn has an evaluation sheet of standards to which the prime equipment must perform if the generator has been properly connected and adjusted. As the test subject demonstrates the use of the generator, the TA completes the evaluation on each output specifications.

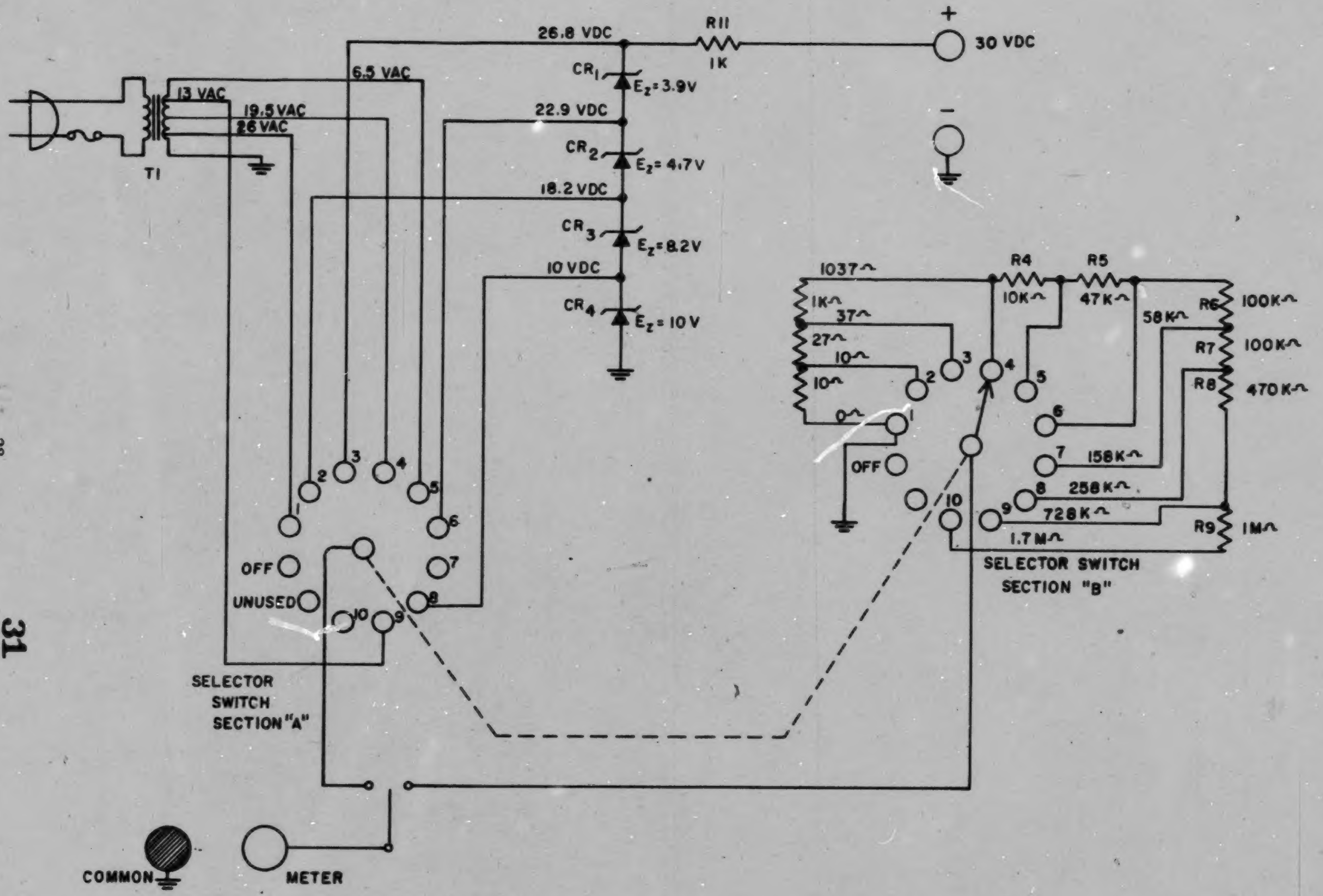

26.8 VDC
R11
1K
+
30 VDC
−
CR1
Ez=3.9V
22.9 VDC
CR2
Ez=4.7V
18.2 VDC
CR3
Ez=8.2V
10 VDC
CR4
Ez=10V
13 VAC
6.5 VAC
19.5 VAC
26 VAC
T1
1
2
3
4
5
6
7
8
9
10
OFF
UNUSED
SELECTOR SWITCH SECTION "A"
1037Ω
1KΩ
37Ω
27Ω
10Ω
10Ω
0Ω
R4
10KΩ
R5
47KΩ
58KΩ
R6
100KΩ
R7
100KΩ
R8
470KΩ
R9
1MΩ
158KΩ
258KΩ
728KΩ
1.7MΩ
OFF
SELECTOR SWITCH SECTION "B"
COMMON
METER

Figure 6. **Schematic diagram voltage/resistance test console.**

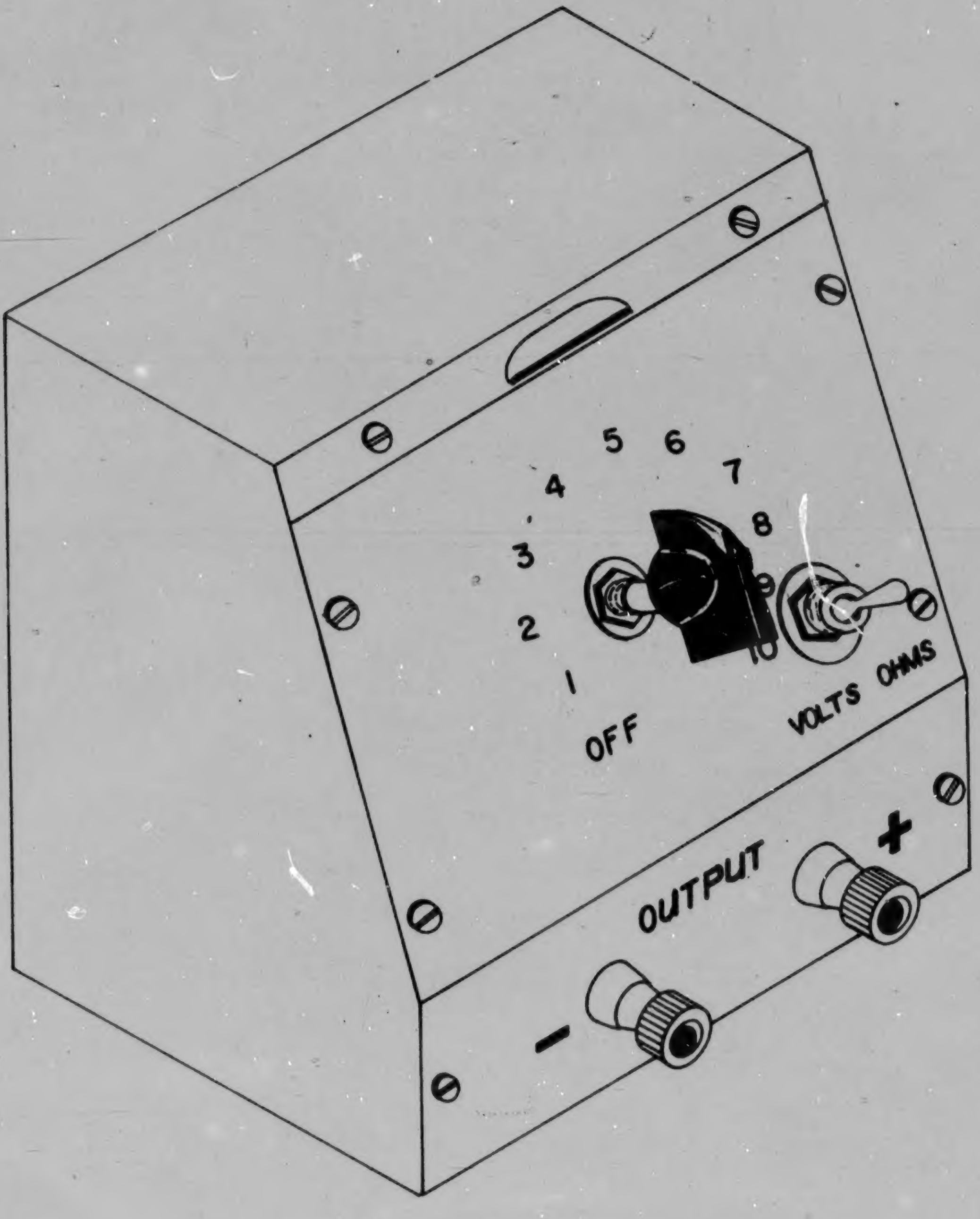

1
2
3
4
5
6
7
8
9
10
OFF
VOLTS
OHMS
OUTPUT
+
-

Figure 7. **Voltage/resistance console.**

Operational Checkout

The equipment checkout task constitutes the beginning and ending point for all other task and job outputs. It consists of making a proper bench setup of the prime equipment and the doppler generator, and then exercising the equipment according to TO procedures to ascertain that it is functioning properly.

For test purposes the TA, after checking that the equipment is functioning properly, disconnects the bench setup. The test subject is then required to re-establish the checkout setup and demonstrate to the TA, via operational checks, that the equipment is functioning properly. The TA then records whether or not the test subject was able to perform the required demonstration. The TA scores the performance in a go, no-go manner depending on whether all the outputs are according to job specifications or not. In addition, there is considerable diagnostic information available which could be recorded if desired.

At the present time, it is felt that the Checkout and Doppler Generator subtests are too similar to be separate, and the Doppler Generator Test should be eliminated. The ability of the test subject to connect the wiring harness *might be* kept as a separate subtest, but a man could easily go through years of job duty without having to perform this task.

Removal and Replacement Tests

The technician must disassemble and assemble the prime equipment in order to carry out his trouble-shooting and alignment tasks and to replace faulty components when found. This subtest consists of identification of the proper component and proper use of hand tools so as not to damage the equipment or components. A series of typical components, that the test subject has to remove and replace on the AN/APN-147-AN/ASN-35 system, was identified. Each item constitutes a separate test in which he must:

1. Insure that the test equipment is functioning properly (perform operational check-out which will be already set up for him).
2. Locate the component specified for removal.
3. Remove the component from the equipment and show it to the TA.
4. Replace the component in the equipment.
5. Deomonstrate proper component replacement by performing on operational check-out for the TA.

The TA will evaluate and record the subject's performance on these tests. The subject will be scored on the basis of whether he removed the right component and whether the equipment functioned correctly upon re-assembly. To aid the TA, a series of photographs is provided showing the equipment and the component in both their assembled and disassembled configurations. This test series does not include removal and replacement tasks that require soldering. Due to the high probability of equipment degradation, all soldering skills are evaluated separately in a subtest utilizing expendable components.

Soldering Tests

This series of tests was provided to cover the soldering tasks. The soldering task consists of several associated elements. Viewed in sequence, the total soldering task proceeds as follows:

1. Unsolder while disconnecting the proper leads to remove faulty component.
2. Select proper replacement component.
3. Install replacement component.
4. Re-connect all associated leads.
5. Solder.

The soldering tasks related to the AN/APN-147-AN/ASN-35 are of two types – conventional wire circuitry and circuit boards. To test both types, as well as soldering and associated tasks, two subtests were devised. One test requires modification of a conventional circuit and the other requires circuit board soldering.

For the conventional circuit soldering, a dummy circuit was built and installed in a box of moderate confinement. In this test the range of soldering tasks described above are evaluated. The TA must inspect the test subject's work to insure that the proper component was removed, that the proper replacement was installed, that the replacement was installed with the correct polarity, that excessive heat was not generated on associated parts during soldering, and that a good solder joint resulted. To perform this evaluation, the TA has a checklist, and the beginning and ending configuration schematics. The TA must treat the leads of the test circuit with heat sensitive material that liquifies if too much heat is applied in soldering. A schematic diagram of the starting configuration is shown in Figure 8, and a drawing of the enclosure is shown in Figure 9.

The second subtest, is conducted on a circuit board. The test subject is told what component to remove and which replacement to use. When he has completed the replacement, the TA inspects each solder-joint and compares it with pictorial representations of acceptable and unacceptable soldering. He then records his evaluation of the soldering on an evaluation sheet.

Summary

The framework of subtests developed in this project, their purpose, and the approach used are summarized in Table 2. A sample of test materials including the test subjects information and identification sheet, test instructions and answer sheets are displayed in Appendix A. In addition, a complete copy of instructions for each test subject for all the JTPT developed together with the Test Administrator's handbook are provided under separate cover as AFHRL-TR-74-57(II), Part II.

SECTION III. ADMINISTRATIVE, SCORING AND DIAGNOSTIC CONSIDERATIONS

Introduction

Some of the administrative and scoring considerations have already been discussed in the preceding sections as they pertained to the test development technology and to the actual test development. The rationale of dependent maintenance tasks for electronic equipment maintenance, as well as, scoring considerations for these tests also have been discussed. But no scheme for systematically recording these scores and applying the rationale has been provided. A proposed profile for recording and analyzing test results in the light of the dependency rationale is presented in this section.

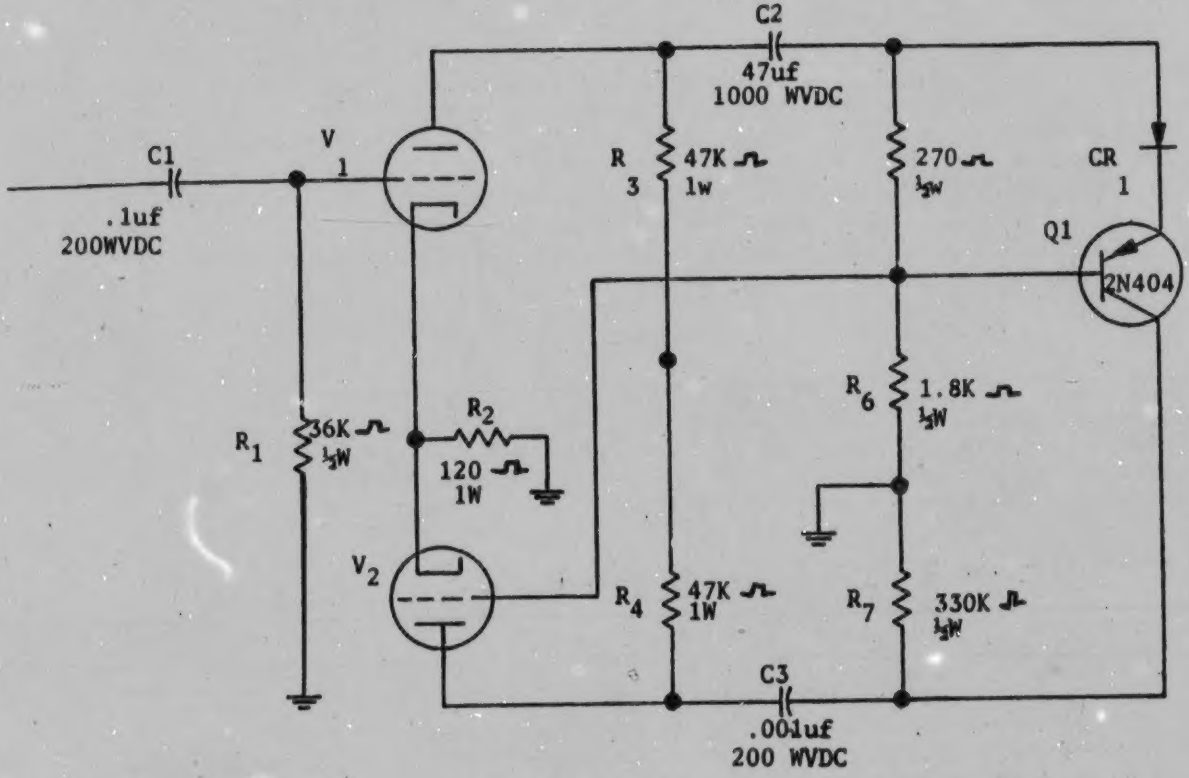
Additional diagnostic information is provided by detailed descriptions of the scoring scheme associated with each individual test and a description of the diagnostic information provided by each test. Other considerations include individual and group uses of test as well as test security considerations.

The Reporting of Test Results

Tests, Problems and Scorable Results

The scoring rationale used throughout these tests is that only specifications of job products are measured and each of these job products is scored on a "go, no-go" basis. Table 2 indicates that tests have been prepared for seven classes of tasks; namely, (1) checkout, (2) physical skill tasks (soldering), (3) remove and replace, (4) test equipment, (5) adjustment, (6) alignment, and (7) troubleshooting.

Table 3 summarizes the number of tests, problems, and scorable products by class of tests developed for the AN/APN-147 and AN/ASN-35. The simple addition of numbers shown in Table 3 indicates that there are 48 tests, 81 problems, and 133 scorable products. But these numbers tell us nothing in terms of the content of the tests. To say that one test subject accomplished 100 scorable products while another accomplished 90 tells us nothing about the job readiness of either of these individuals or that one is better than the other. The varieties of scorable products are so diverse that any combination of them without regard to what they represent is meaningless. The only meaningful presentation of such information must be in terms of a profile designed to attach meaning to such numbers. A sample of such a profile is shown in Figure 10.



C2
47uf
1000 WVDC
C1
.1uf
200WVDC
V 1
R 3
47K Ω
1w
270 Ω
½W
CR 1
Q1
2N404
R6
1.8K Ω
½W
R1
36K Ω
½W
R2
120 Ω
1W
V2
R4
47K Ω
1W
R7
330K Ω
½W
C3
.001uf
200 WVDC

Figure 8. **Schematic diagram, wire circuit soldering.**

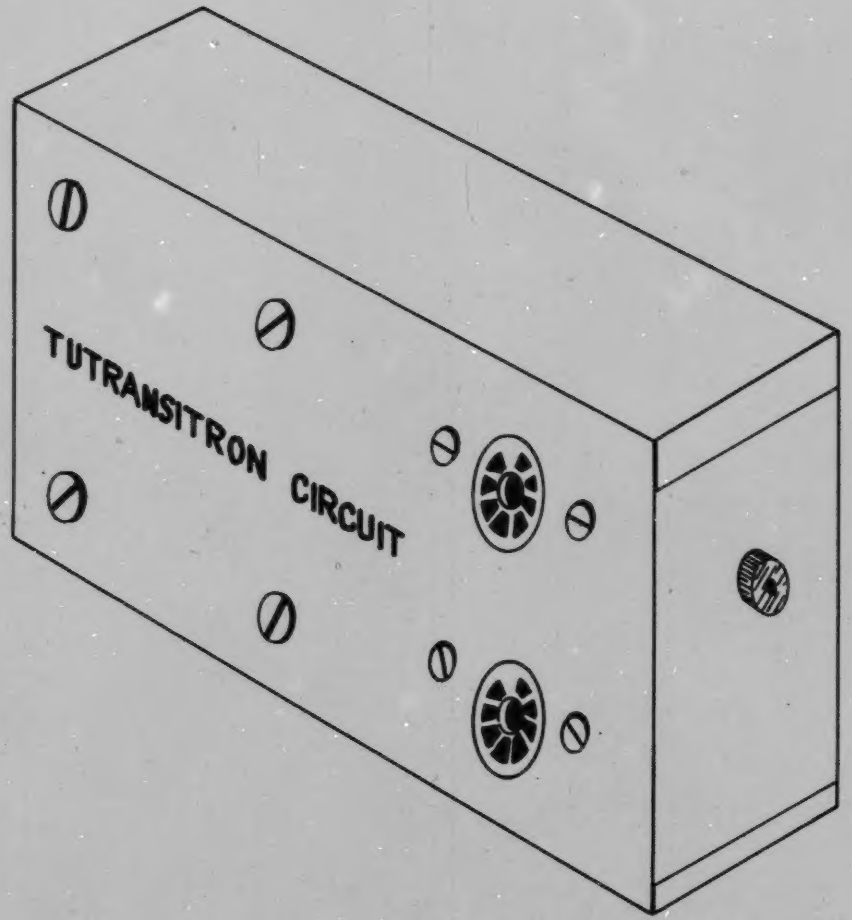

TUTRANSITRON CIRCUIT

Figure 9. Wire circuit soldering enclosure.

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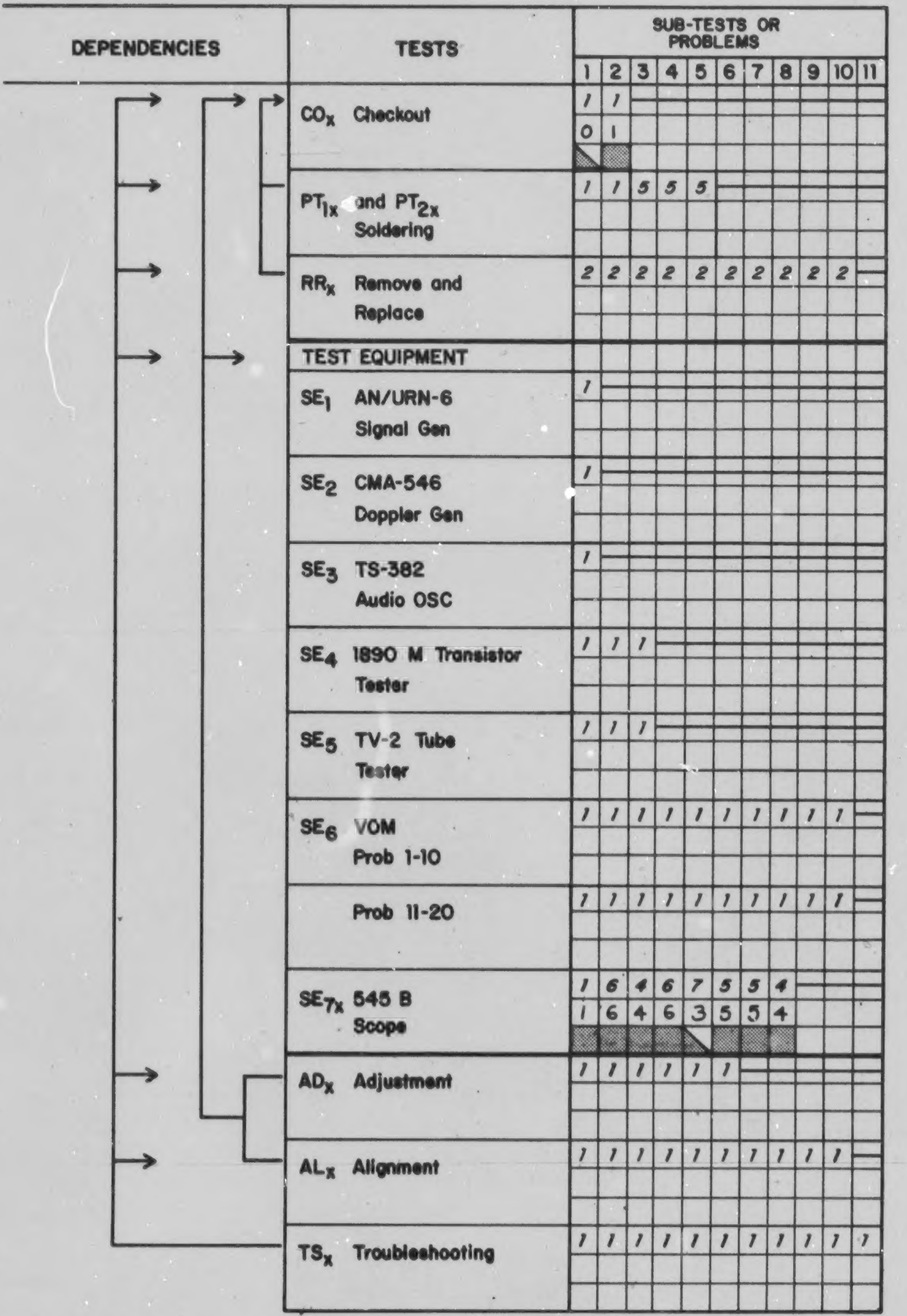
Table 2. **Major Test Classes**

TEST CLASS	PURPOSE	APPROACH
Alignment (AL Series)	To determine whether a technician can perform a representative set of alignments on the AN/APN-147-AN/ASN-35 system.	A specific alignment parameter is thrown out of tolerance and the technician must demonstrate that he can realign the system.
Adjustment (AD Series)	To determine whether a technician can perform a representative series of adjustments on the AN/APN-147-AN/ASN-35 system.	As specific adjustment is thrown out of tolerance and the technician must demonstrate that he can readjust the equipment.
Troubleshooting (TS Series)	To determine whether a technician can locate and identify specific within-stage and between-stage faults in the prime equipment.	A specific fault is inserted into the equipment and the technician must locate and identify the faulty component.
Test Equipment Usage (SE Series)	To determine whether a technician can properly use the test equipment specific to his work assignment.	The technician is required to use a specific item of test equipment and demonstrate that he can properly utilize the features of that item.
Removal and Replacement (RR Series)	To determine whether a technician can correctly identify, remove, and replace a prime equipment module and retain the set in an operational status.	Modules will be specified for the test subject to remove and replace and upon completion, the operational status of the equipment will be checked.
Peripheral (PT Series)	To determine whether a technician can solder properly under job conditions.	The technician must properly identify, remove and replace a soldered piece part in a test circuit.
Check-Out (CO Series)	To determine whether a technician can properly connect the subject prime equipment to its bench test set-up configuration and perform operational check-out of system.	Require the technician to connect the prime equipment to the bench test set-up and demonstrate that the required systems checks can be made.

Table 3. Tests, Problems, and Scorable Products

Classes	Code	# Tests	# Problems	# Scorable Products
1. Checkout	CO	2	2	2
2. Physical Skill Tasks (soldering)	PT	2	5	17
3. Remove & Replace	RR	10	10	20
4. Test equipment	SE	7	37	67
5. Adjustment	AD	6	6	6
6. Alignment	AL	10	10	10
7. Troubleshooting	TS	11	11	11
Total	7	48	81	133



TESTS	1	2	3	4	5	6	7	8	9	10	11
CO_x Checkout	1	1									
	0	1									
	▨	▨									
PT_{1x} and PT_{2x} Soldering	1	1	5	5	5						
RR_x Remove and Replace	2	2	2	2	2	2	2	2	2	2	
TEST EQUIPMENT											
SE_1 AN/URN-6 Signal Gen	1										
SE_2 CMA-546 Doppler Gen	1										
SE_3 TS-382 Audio OSC	1										
SE_4 1890 M Transistor Tester	1	1	1								
SE_5 TV-2 Tube Tester	1	1	1								
SE_6 VOM Prob 1-10	1	1	1	1	1	1	1	1	1	1	
Prob 11-20	1	1	1	1	1	1	1	1	1	1	
SE_{7x} 545 B Scope	1	6	4	6	7	5	5	4			
	1	6	4	6	3	5	5	4			
	▨	▨	▨	▨	▨	▨	▨	▨			
AD_x Adjustment	1	1	1	1	1	1					
AL_x Alignment	1	1	1	1	1	1	1	1	1	1	
TS_x Troubleshooting	1	1	1	1	1	1	1	1	1	1	1

Figure 10. A profile for displaying the results obtained by an individual subject from a Battery of Job Task Performance Tests concerning an Electronic System – the AN/APN-147 and the AN/ASN-35. The results for only two tests are indicated.

A Profile for Reporting Test Results

The profile provides reporting information and space for each problem. For example: there are only two checkout tests; one for the AN/APN-147 and one for the AN/ASN-35. Each of these checkout tests represents a single maintenance problem. For each of these problems, there is only one output or product to be measured. When scored on a "go, no-go" basis, a test subject can receive only a 1 or 0 for either of these problems. This represents the case of one test, one problem, one scorable product.

If a test subject took the two checkout tests and demonstrated that he could perform the checkout of the AN/ASN-35 (Test 2) but was unable to perform the checkout of the AN/APN-147 (Test 1), these results would appear as follows on the profile chart.

	TESTS	1	2		
	CO_x Checkout	1	1		Possible score
		0	1		Earned score
		◪	■		Bar presentation

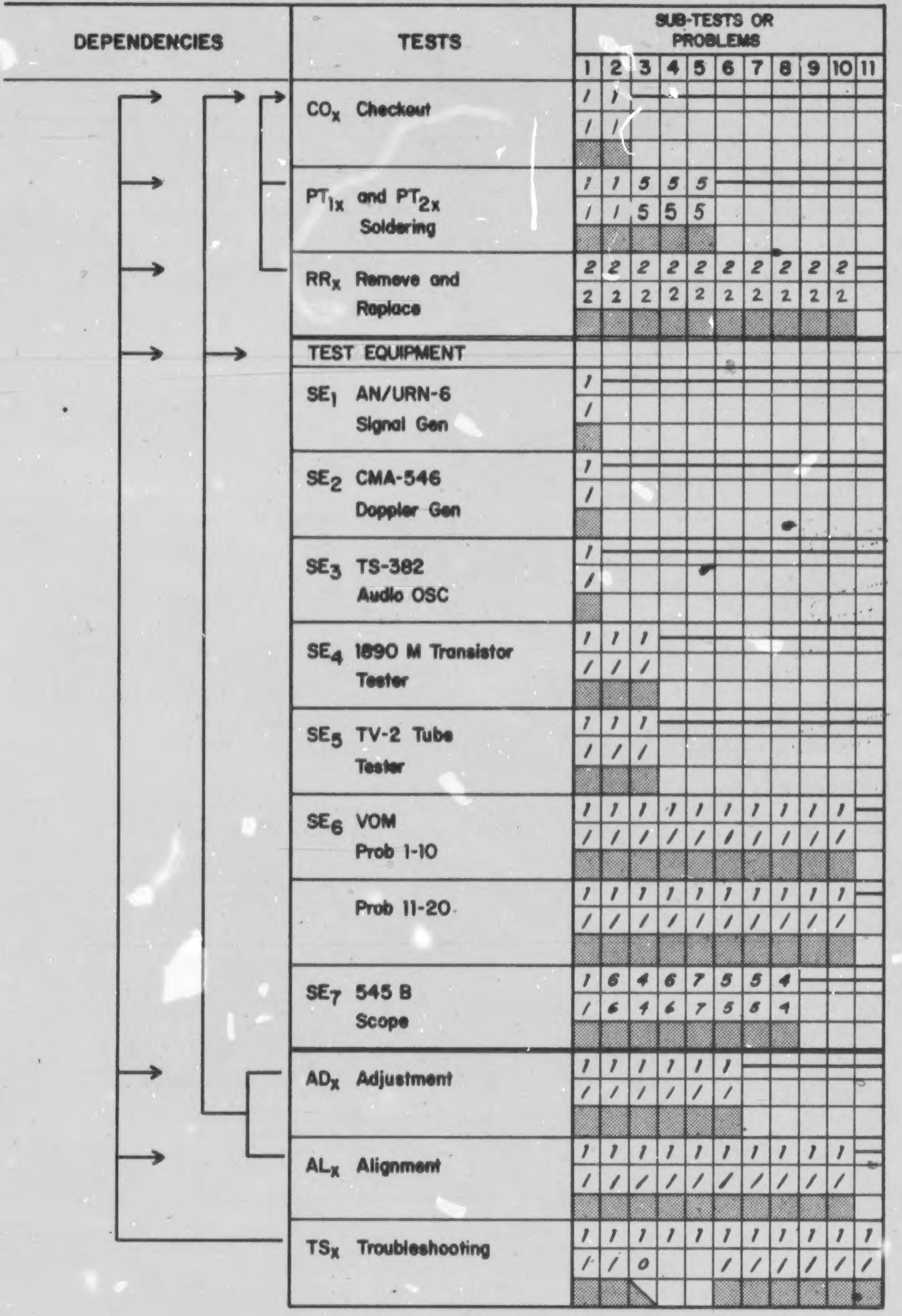
The "0" shown in line 2 for Test 1 indicates that the test subject was unable to accomplish Test 1. The half filled cell (◪) on line 3 under Test 1 indicates that the subject has tried Test 1 but has failed. The "1" shown on line 2 for Test 2 indicates that the subject successfully accomplished Test 2. The filled cell (■) on line 3 presents this same information in bar form. If the subject had performed both checkout tasks successfully, the bar would of course be solid.

The oscilloscope test (SE_7) within the test equipment area represents another case. These are eight problems in this test. Most of these problems contain more than one scorable product. For example, problem 2 contains six scorable products. But the test subject *must* obtain all six scorable products or a score of "6" to receive a "go" on this *problem*. Since there are eight problems, the subject must receive eight "go's" to indicate proficiency in the use of the oscilloscope. As an example (next profile chart), a test subject was able to perform all the problems except problem 5 and on problem 5 he only obtained three of the seven products.

	TESTS	1	2	3	4	5	6	7	8	
	$SE_{7x}545B$	1	6	4	6	7	5	5	4	
	SCOPE	1	6	4	6	3	5	5	4	
		■	■	■	■	◪	■	■	■	

A glance at the bar ofsthe profile indicates that the subject has tried all problems of the oscilloscope test, and that he has successfully performed all but one of the problems. It, also, tells us that he is not fully qualified on the oscilloscope and will not be until he can perform the operations called for by problem 5. The objective of course is full qualification.

A nearly complete profile is shown in Figure 11. This profile indicates that the subject has demonstrated his ability to perform all of the test problems down to troubleshooting. To date, he has attempted nine of the eleven troubleshooting tests and successfully completed eight of the nine tests. He, therefore, is not completely qualified in troubleshooting.



TESTS	SUB-TESTS OR PROBLEMS 1	2	3	4	5	6	7	8	9	10	11
CO$_x$ Checkout	1	1									
	1	1									
	▨	▨									
PT$_{1x}$ and PT$_{2x}$ Soldering	1	1	5	5	5						
	1	1	5	5	5						
	▨	▨	▨	▨	▨						
RR$_x$ Remove and Replace	2	2	2	2	2	2	2	2	2	2	
	2	2	2	2	2	2	2	2	2	2	
	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
TEST EQUIPMENT											
SE$_1$ AN/URN-6 Signal Gen	1										
	1										
	▨										
SE$_2$ CMA-546 Doppler Gen	1										
	1										
	▨										
SE$_3$ TS-382 Audio OSC	1										
	1										
	▨										
SE$_4$ 1890 M Transistor Tester	1	1	1								
	1	1	1								
	▨	▨	▨								
SE$_5$ TV-2 Tube Tester	1	1	1								
	1	1	1								
	▨	▨	▨								
SE$_6$ VOM Prob 1-10	1	1	1	1	1	1	1	1	1	1	
	1	1	1	1	1	1	1	1	1	1	
	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Prob 11-20	1	1	1	1	1	1	1	1	1	1	
	1	1	1	1	1	1	1	1	1	1	
	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
SE$_7$ 545 B Scope	1	6	4	6	7	5	5	4			
	1	6	4	6	7	5	5	4			
	▨	▨	▨	▨	▨	▨	▨	▨			
AD$_x$ Adjustment	1	1	1	1	1	1					
	1	1	1	1	1	1					
	▨	▨	▨	▨	▨	▨					
AL$_x$ Alignment	1	1	1	1	1	1	1	1	1	1	
	1	1	1	1	1	1	1	1	1	1	
	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
TS$_x$ Troubleshooting	1	1	1	1	1	1	1	1	1	1	1
	1	1	0			1	1	1	1	1	1
	▨	▨				▨	▨	▨	▨	▨	▨

Figure 11. A profile for displaying the results obtained by an individual subject from a battery of Job Task Performance Tests concerning an Electronic System – the AN/APN-147 and the AN/ASN-35. This represents the profile of an individual who has successfully completed most of the battery.

This profile is not presented as the final solution to the profile problem for JTPT for electronic maintenance. It does contain most of the important information regarding a test subject's success on the full range of tests. It gives a meaningful picture of the subject's job abilities as measured by the test battery, indicating the subject's strengths and weaknesses. An examination of the profile (Figure 11) indicates that most of the tests in this battery contain only one problem. For example, there are two checkout tests, having one problem each and there are eleven troubleshooting tests having one problem each. There are two soldering tests; one has two problems and the other has three. The Voltohmmeter (VOM) test has 20 problems. The subject receives no "credit" for a problem unless he obtains all of the expected products. *No attempt is made, to combine these scores in terms of meaningless numbers.*

Proposed uses of these tests and of this profile in field maintenance unit, formal training and research environments will be discussed in Section VI of this report. The dependency column of the profile will be discussed later under diagnostics.

JTPT as Analytical and Diagnostic Tools

Diagnostics have come to have a rather negative connotation – that of identifying faults and ascertaining what has caused the faults. Criterion referenced JTPT if properly structured and used can provide a large amount of such diagnostics concerning what is wrong with the world of maintenance. They, also, can provide a great deal of information concerning what is right with the world of maintenance. (The word analytical has been added to the subtitle to reflect these positive aspects of the use of JTPT). The following paragraphs are concerned with ways and means for obtaining specifics about the world of maintenance.

Job Readiness. There are a great many contention concerning what it takes and how long it takes a new enlistee to become "job ready," but there is little hard data concerning the empirical or job related validity of these contentions. In fact, we do not know a great deal about how truly "job ready" people with many years of maintenance experience are to say nothing about new people. A valid question follows – What will a battery of JTPT (such as those developed during this effort) tell us about an individual's "job readiness?" And the answer is a great deal if properly utilized – certainly a great deal more than scores obtained on a job knowledge test (such as the Specialty Knowledge Test) or scores obtained from tests on electronic theory.

As discussed earlier, the test battery has been designed so that the pattern of successful and unsuccessful test performance indicated by the profile gives a good indication of the job readiness of an individual. The hierarchy of job activities and their dependencies are reflected graphically in the dependency column of the profile (Figures 10 and 11). A *successful* trouble isolation and repair activity, for example, is *always* dependent on a technician's ability to check out his equipment; it is *almost always* dependent on his ability to align and adjust; and it *may be* dependent on his ability to remove and replace defective items including in some cases his ability to solder. If an alignment or adjustment activity is considered to be a maintenance activity in its own right, a similar set of dependencies becomes apparent. The successful accomplishment of such an activity is dependent on the maintenance man's ability to check out his equipment and to use test equipment.

Returning to the troubleshooting activity, if a test subject is given a troubleshooting problem and is unable to find the trouble, the failure could be a result of his inability to perform any one or a combination of the dependent activities discussed above. Without further information we can only guess as to why. But if we apply the whole test battery and the proposed profile to the diagnosis and find that he cannot use his test equipment well, we know that at least one part of his troubleshooting weaknesses is his inability to use test equipment. If this weakness is corrected and he still has difficulty troubleshooting by the process of elimination, we can conclude that his troubleshooting strategy is faulty.

From a further projection of this dependency rationale, we can conclude that a technician should demonstrate his ability to perform checkout procedures, to use his test equipment, to perform remove and replace procedures and to perform align and adjust procedures before he is permitted to perform troubleshooting. In like manner, he should not be tested on his ability to troubleshoot until his test profile indicates that he is proficient in these dependent activities.

The test profile will provide the maintenance supervisor and manager and the training supervisor with an instrument which will tell them the *degree* to which an individual is *job ready*. The lowest *step* in job readiness is, of course, the subject's ability to perform his checkout procedures. The highest *step* in this structure of progression would of course be his ability to troubleshoot.

In the use of such a profile, supervisors and managers should not conclude that because an individual's profile of tests taken a year or two in the past is still valid. The subject may have lost his proficiency in some important areas through lack of use-in the same manner, as a pilot loses his proficiency to operate an aircraft. More will be said about maintenance of proficiency later.

In addition to the major diagnostic information to be obtained from the tests profile just described, Appendix B (Table B1) provides a description in tabular form of additional diagnostic information available for each test in the battery. This appendix also provides a short description of each test and a description of the product or products expected from each test. These are important items of information for the description of maintenance weaknesses identified by the profile.

The Role of the Test Administrator (TA)

The role of the TA was briefly discussed in Section II in conjunction with the rationale for developing the troubleshooting tests where it was indicated that the TA should not be permitted to prompt test subjects. In regard to diagnosis, it might be argued that the TA can diagnose individual's difficulties from watching his overall performance. The TA can be said to represent any number of roles. He can stand for the job supervisor who wants to know what quality product he is getting. He could stand for the training school that wants to know what kind of product they have turned out. He could stand for the research scientist who has developed a new method of documentation or training and wants to know how good it is. He also could stand for the analyst who is trying to determine *why* the test subject fails to perform perfectly. The TA can be said to represent all those roles. But in the present research, a model has been designed to take on all of these roles in an objective manner. In this model test, the TA exercises virtually no judgment except to say whether certain products produced during the test meet the product specifications. Other than that, he has the role of a traffic cop—to see that test subjects move smoothly through the testing process, without prompting. The framework of subtests and classes of test items available in the present test battery provides a much more objective type of diagnosis regardless of who is the TA.

Job Coverage

Although a great deal can be learned from the proper application of the test profile, it won't tell us everything; and the level of confidence is greater for some testing activities than for others.

Checkout Procedures. The job coverage of checkout procedures is of course complete. There is one checkout procedure for the AN/APN-147 and another for the AN/ASN-35. If an individual performs these activities under test conditions, we can be confident that he *can* perform all checkout procedures.

Use of Test Equipment. The coverage of the uses of test equipment for the AN/APN-147 and AN/ASN-35 also is complete. If an individual can generate the products as called for by these test equipment tests, we can be confident that he *can* use his test equipment with the AN/APN-147 and AN/ASN-35. The VOM and Oscilloscope tests have more general application. Even with their current coverage, we can be reasonably confident that an individual who can perform these test problems successfully can perform most of the capabilities of the VOM and the oscilloscope. *With some expansion, all capabilities could be included.* The test concerning the transistor and tube checking include all of the capabilities of these test equipments.

Alignment, Adjustment and Calibration. The sample of problems concerning alignment and adjustment is large and covers very typical activities. As a result, we can be reasonably confident that subjects who perform these problems successfully can perform the alignments, adjustments and calibrations required by the organizational and intermdediate levels of maintenance for the AN/APN-147 and the AN/ASN-35.

Remove and Replace The sample of remove and replace problems is rather large and the problems are typical. In addition, most remove and replace actions are not too difficult. As a result, we can be reasonably confident that subjects who perform the ten remove and replace tests can perform all remove actions for the AN/APN-147 and the AN/ASN-35.

Troubleshooting. The testing of troubleshooting ability would seem to present a much greater sampling problem than the other testing areas just discussed. This would seem to be especially true when considering equipments such as the AN/APN-147 and the AN/ASN-35 which contain what is now considered older circuit technology. The AN/APN-147, for example, contains approximately 14000 Field Replaceable Units (FRU), each of which represents a potential fault to be isolated. Equipments which reflect more modern electronic technology have much fewer FRU. The Inertial Doppler Navigational Equipment (IDNE) on the C-5 aircraft, for example, contains only 28 FRU. The AN/APN-147 and the IDNE perform much the same operational functions. (The fewer FRU of course reduce the difficulty of test sampling as well as the difficulty of troubleshooting itself for the organizational and intermediate levels of maintenance.)

When considered from the point of view of the number of possible troubles in the AN/APN-147 and the AN/ASN-35, a battery of only 11 troubleshooting tests is certainly a small sample. Considered as an isolated and independent test battery, such troubleshooting tests would certainly not tell us much about an individual's ability to troubleshoot, especially when we consider the many different human abilities or factors called for by the troubeshooting process.

But when, considered in light of the entire battery of maintenance JTPT, we have a different sampling problem. If the test battery is administered as recommended, we will have previously determined that the test subject is proficient in all of the important troubleshooting sub-activities except his cognitive activity of applying a troubleshooting scheme or logic or strategy (whichever we wish to call it). What we are primarily measuring under these conditions is the effectiveness of the test subject's troubleshooting strategy in a realistic job environment (which includes the normal interference of information gathering activities). The normal model of a troubleshooting strategy is the troubleshooting tree. There are fewer branches in any troubleshooting tree than the number of possible troubles. Another way of saying this is that each branch of a troubleshooting tree has many trouble signatures. The 11 troubleshooting tests require the test subject to sample all the main branches and many of the sub-branches of his troubleshooting strategy. As a result, the 11 tests sample the branches of his troubleshooting strategy rather well. If the subject can solve these 11 troubleshooting problems, we can reasonably assume that he will be able to find most of the possible troubles in this equipment. *But this rationale is only valid if he has previously demonstrated his sub-abilities on the other subtests of the battery before he is given the troubleshooting tests.* Under these conditions the writers are of the opinion that the trouble-shooting sub-battery, becomes a powerful test instrument for determining whether or not the test subject can effectively troubleshoot the AN/APN-147 and AN/ASN-35.

Innate Ability, Acquired Ability and Motivation

When an individual performs a task in the test situation, it can usually be considered his maximum effort at the time of the test. This effort will usually be somewhat greater than he would normally exert to perform the same task in a normal job situation. Such differences must be considered in interpreting the results of JTPT.

An individual brings to a test situation or to his job situation at least three determinants—his innate ability, his acquired ability, and his motivation. Most individuals will make a special effort to increase their acquired ability *prior* to a test, if they know or think they know which tasks they are going to be required to perform. They will do this by practicing these tasks. In addition, they will be motivated to make a maximum effort during the test. For these two reasons, a test is normally a maximum effort situation.

The JTPT such as developed for this effort can determine the test subject's *ability* (innate plus acquired) to perform the tasks of his job. Such tests will not predict how well the subject will be motivated to perform these tasks on the job. It, also, is difficult to predict how long an individual will retain his ability to perform tasks after he is tested. If he does not continue to practice their performance, he will lose his proficiency. This rate of loss will vary from individual to individual, and will be greatly influenced by how well the performance of the task has been learned. It is, therefore, important that an individual "over learn" the performance of important tasks. It, also, follows that he should be tested frequently on important tasks to motivate him to practice enough to maintain a high level of proficiency.

Group vs Individual Measurement

So far, our discussion concerning test administration and scoring has been orientated toward the measuring of the individual. It is sometimes desirable to know how well as group such as a maintenance unit or a graduating class can perform. The ideal way to ascertain such group information would be to give each member of the group the full battery of JTPT. But many times maintenance and training supervisors or administrators do not think thatsthey have the time nor the resources for such extensive testing. In such cases, a great deal can be learned about the group by administering the entire battery to representative individuals of the group or by administering selected tests of the battery to the entire group or to selected representatives of the group. The profile developed earlier can be modified to accommodate such administrations. More will be said about these considerations in Section VI concerning suggested applications.

Test Security

Test security for "objective" type written tests has always been a problem. If a test subject is able to acquire a key to such a test (even if the key is not exact), it becomes rather easy for him to learn the necessary numbers, words, or word chains for obtaining a good score without knowing the subject matter the test is sampling. With most of the subtests of this test battery, we do not have this problem. We are interested in the test subject performing typical tasks of his job. If he practices these tasks in preparation for a test, which he knows he issgoing to have, so much the better. His good performance on the test will result in better performance on the job.

For example, the test subjectsknows he is going to have a performance test on checkout procedures. He knows that there is only one checkout procedure for each equipment. He knows that the checkout procedure is in the TO. He, also, should know that most TO checkout procedures are not entirely complete and should be practiced if he expects to receive a passing score. If he practices his checkout procedures before the tests, he will not only perform better on the test but he, also, will perform the checkout procedure better on the job. If he already can perform the checkout procedure, the added practice will contribute to desirable "over learning." This will contribute to his long range retention of the skill and to the better transfer of his checkout skill to unfamiliar equipments. Much the same can be said for the remove and replace tests, the soldering tests, the align/adjust tests, and the test equipment tests.

There could possibly be some compromise of the VOM tests if the exact voltage and resistance reading should happen to be known by test subjects. These values, however, can be modified very easily and should therefore be changed frequently. The short cut scoring scheme used in the oscilloscope tests could possibly result in minor compromise. But the oscilloscope tests are so complex that it is doubtful that such knowledge would help a test subject unless he already knows a great deal about using the oscilloscope.

The compromise of the "bugs" of troubleshooting tests could easily become a problem. The troubleshooting tests have two common characteristics with "objective" type written test items. There is only one right answer and the tests cover only a sample of the "subject matter." Precautions can be taken to overcome these weaknesses. The orders of administration should be different for every test subject. Equivalent tests can be produced for each test by faulting different signatures of the same subbranches of the troubleshooting tree. This would result in different faults giving the same or similar symptoms. Various combinations of equivalent tests could then be administered so that no two test subjects would receive the same combination of tests during any administration.

If the test battery is administered as recommended, most of the abilities support troubleshooting will have been measured previously by performance tests which cannot be easily compromised. This would reduce the number of people taking the troubleshooting tests before having the necessary supporting maintenance skills. The temptation to cheat on the troubleshooting tests would thus be greatly reduced.

SECTION IV. TEST ADMINSTRATORS' MANUAL AND TRAINING PROGRAM FOR TEST ADMINISTRATORS

The previous sections have discussed the JTPT development methodology; have described the development of a series of 48 JTPT in keeping with this methodology; and have discussed administrative, scoring and diagnostic considerations. No system of testing is complete until adequate instructions for test administration are available. In addition, the writers felt that a training program for TA, if not necessary, was highly desirable. This section is devoted to a description of the development of an administrator's manual as well as to a training program for TA.

The Development of Instructions for The Administration of Job Task Performance Tests (JTPT)

As discussed previously, JTPT were structured to facilitate administration as much as possible. *What was now required were instructions on test administration procedures that were sufficiently detailed to permit administrative personnel, without extensive electronics backgrounds, to accurately administer the tests and evaluate performance.* The basis for presuming that such personnel could be so utilized is the work which has been done for the Air Force on proceduralized job performance aids.

Beginning with a number of AFHRL studies early in the 1960's, a set of techniques has been evolving for presenting complex job task instructions to relatively untrained personnel in such a manner that they could follow them and satisfactorily perform the tasks (Foley, 1973). Generally, the techniques involve breaking down the task into short, clear instructions, and giving an abundance of graphic support to the instructions. A sample of proceduralized instructions developed for the TA is included as Appendix C to this document. A complete set is provided as Part II of this Volume. The main elements of these instructions are:

1. general information on how to organize and control the test administration environment;
2. orientation to the AN/APN-147 radar and its associated AN/ASN-35 computer;
3. specific step-by-step instructions on all aspects of each performance test, from set-up to evaluation and recovery.

General Administration Information and Equipment Orientation

The general administration information covers such topics as overall support requirements, safety precautions required, test security considerations, and how to structure the testing environment. The orientation materials on the radar set and computer cover in detail the configuration, functioning and standard checkout procedures that pertain. The information in both of these sections is supplemented by the training program, discussed later.

Specific Step-by-Step Instructions

The instructions for administering each test are set up so that the TA can follow each step in sequence for complete test administration. The support materials and equipment required are specified first (both in text and graphics) and then the TA is told how to set up the test problem. In cases where problem set up requires maladjustment of the radar equipment or other complex problems, the test instructions provide graphic depictions of each step to support the written instructions. The same type of detail is provided for evaluating test subject performance. The results which are to be obtained are depicted in both textual and graphic formats.

An important part of test administration, especially if the TA are not qualified technicians, is recovering from test subject errors. When a test subject is unsure of himself, he may make some random attempts to solve the problem. This results in the equipment having additional malfunctions put into it besides the known test problem, or else the original problem is increased. As part of the testing package, the TA is provided a series of adjustment gauges which can be used to set critical parameters of the equipment without the use of test equipment. While this does not do the same caliber of job as would be required by normal maintenance standards, it does keep the equipment operational and permit testing to continue.

Not included as part of the original Test Administrator's Manual package are the evaluation and other administrative forms required. Due to the volume of materials, these were provided with the instructional materials for the test subjects as part of the original test development package. Both the Test Administor's Manual and the Test Subject's Instructions are now packaged in Part II of this volume. Neither the current administrator's manual nor the test package contains the scoring profile presented in Figures 10 and 11, Section III. This performance test project has been developmental. The profile was developed after the original JTPT and the administrator's manual had been developed and tried out. Such a profile should certainly be included as the reporting device for test results in any future test administration or development.

Training Program Development

The training program was developed, as were the test administration instructions, for individuals with little electronics background. It is geared to completely familiarizing the TA to the radar set and computer and consists of:

1. Instruction on the mechanics of conducting JTPT, to include: scheduling, test security, simulataneous testing, and recording scores and other administrative data.
2. Video tape of correction criterion performance of each of the JTPT on live equipment.
3. Demonstration on actual equipment without power.
4. Instruction on how to recover from equipment malfunctions induced by test subjects' errors.
5. Practical exercises in test administration.

Figure 12 shows the breakdown of the time allocated to the training program.

SECTION V. TRYOUT OF JOB TASK PERFORMANCE TEST (JTPT) SYSTEM

Purpose and Extent of Tryout

The main thrust of the efforts reported in this volume has been concerned with the development of an administratively feasible battery of criterion referenced JTPT and adequate scoring schemes for the key tasks of electronic maintenance. The previous sections of this volume describe the test development methodology, the 48 JTPT developed, a scoring profile, the Test Administerator's Manual and a training program for Test Administrators. During the development of these tests, every effort was made to assure that each, test required the test subject to perform a typical job task. *As discussed in AFHRL-TR-74-57(I), these tests were designed to approach the ultimate job criterion as closely as possible. As a result, no validation of their empirical validity is possible. They are empirically valid by definition.*

The main objective of the tryout was the ascertain whether or not the testing system was administrable. During their initial development, each of the 48 tests was administered to at *least two* experienced technicians at McGuire Air Force Base, New Jersey. Some tests were administered *three times* at McGuire. The Administrator's Manual also, was checked out at McGuire. After necessary "debugging" of the Test Subject's Instructions and the Test Administrator's Manual, *two* members of the Military Airlift Command's (MAC) Maintenance Standarization Evaluation Team (MSET) were trained to administer the JTPT using the Test Administrator's Handbook. During this training program at Scott Air Force Base, Illinois each MSET TA administered every test *at least once*. After being trained the MSET TA administered each JTPT during official field visits to other MAC bases at *least three times*. Each test in the battery therefore was administered at least seven times during the development and tryout efforts described in this volume. *Based upon these test administrations, and upon the performance of the MSET TA when they conducted the JTPT, it can be concluded that the battery of JTPT as constructed can be administered by Air Force Personnel and that meaningful results can be obtained from their administration.* The main objective of ascertaining test administrability therefore was achieved.

HOUR	DAY 1	2	3	4	5
1	PROJECT ORIENTATION	CHECKOUT TEST ADMINISTRATION	REMOVAL AND REPLACEMENT TEST ADMINISTRATION	ALIGNMENT TEST ADMINISTRATION	PRACTICAL EXERCISES
2	RADAR SYSTEM ORIENTATION				
3	PERIPHERAL TEST ADMINISTRATION	SPECIAL EQUIPMENT TEST ADMINISTRATION	ADJUSTMENT TEST ADMINISTRATION		
4					
5	GENERAL TEST EQUIPMENT TEST ADMINISTRATION				REVIEW, CRITIQUES, & PLANNING
6					
7				TROUBLESHOOTING TEST ADMINISTRATION	
8					

Figure 12. Test Administrator training program schedule.

Original plans called for additional field administrations of the JTPT battery to obtain some needed hard data on how well experienced technicians can perform the tasks of their assigned jobs. Due to unfortunate circunstances explained in detail below. This desirable and important secondary objective was not achieved. In this regard the various JTPT administrations described previously to experienced technicians indicated that they could perform checkout and remove/replace tasks. They did fairly well on soldering tasks. However they had trouble with the test equipment tests, the align/adjust tests and the troubleshooting tests. These JTPT were used as criterion tests for the validation of symbolic substitute tests. That effort is described in AFHRL-TR-74-57(III). In that effort eight troubleshooting JTPT were given to 15 experienced technicians. The data obtained in that effort also support the contention that experienced technician cannot troubleshoot very effectively.

The comments that follow concern why MAC units were selected for the trial application described previously as well as some of the administrative difficulties experienced during these application efforts Some suggestions are made for future field applications in MAC.

Selection of Trial Application

As stated previously, the design of criterion referenced JTPT anticipated their use in research projects, in both formal and on the job training, and in field maintenance units. Therefore, realistic implementation of the performance testing system required that the tests be administered in operational units, by Air Force personnel, and in connection with a standard activity of the Air Force. The objective was to reduce as much as possible the "exceptional" nature of the testing activity generally associated with training programs or research projects, and integrate it into an existing activity to provide a more accurate estimate of the feasibility of such testing.

The support of the Military Airlift Command (MAC) was solicited, since they operate Maintenance Standardization Evaluation Teams (MSET). These teams are on a continuing program of evaluating maintenance activities of units within MAC, and they presently use a form of uncontrolled performance evaluation discussed below. This organization represented an area whose mission was thought to be highly compatible with the use of controlled performance testing.

MAC authorities were briefed on the project, its goals and its methods, and they agreed to furnish the services of two of their senior electronics evaluators to conduct the JTPT during their regular evaluation trips on a "time-available" basis.

Tryout of the Training Program

The personnel who were assigned to the project were more highly qualified than had been anticipated. One NCO was fully acquainted with the AN/APN-147 radar and the other had an extensive electronics background. As a result both the test administration instructions and the training program were more detailed than they required. (Program objectives, however, required that the materials be developed for the more general type of test administrator originally anticipated, since it could not be assumed that such highly-qualified personnel would always be available.) Due to the experience of the TA, coverage of this material was completed in about three days instead of five. After a description of the project and its goals, each of the JTPT was reviewed and a video-tape of its correct performance shown. Test administration aids and strategies related to each of the tests were then described and discussed. Practical work was given by taking the TA to a field maintenance shop and having them administer the tests to available technicians.

As the final portion of the training program, the TA described their assigned duties during evaluation visits to MAC installations. Based on this, plans were made for test data collection and for the researchers to accompany the TA during their first subsequent evaluation visit.

Field Tryout of the JTPT

Once the TA were trained, it was planned that they would administer as many JTPT as possible during their inspection visits over a period of several months. Test results would then be sent back to project personnel who would evaluate them and set up a processing system that would begin converting the performance test results into meaningful analytical tools.

At the outset of this phase of the program, two difficulties were encountered. The evaluation philosophy and practices of the MAC MSET program were fundamentally different from objective performance testing. The MSET operated on a policy of *minimum interference with the operations of the unit being evaluated*. They also covered a great deal of unit administrative procedures that were not the subject of the performance tests. In evaluating job or task performance, their approach is to observe technicians performing whatever work is in progress in the shop at the time. They evaluate a technician's performance in terms of use of technical documentation, safety precautions observed, and technical procedures followed. While they may provide some incidental comments or evaluation pertaining to an individual, their primary mission is to rate the overall unit effectiveness according to common standards based on *subjective* judgements.

This policy of not making any additional work conflicted with the requirements of performance testing, since the JTPT are objective measures of individual performance on standard work units under controlled condition. The planned procedures for administrating performance tests require the diversion of personnel from their immediate tasks, even though they may be doing the same or similar work at the time. These procedures insure that the input condition of the equipment must be known and constant, from one individual to another for each given test item.

Since this MAC policy could not be waived during the evaluation period it was agreed that the TA would give such performance tests as there was time for them upon completion of the normal MSET evaluation work. As a result of this arrangement, only three batteries of JTPT were administered during the balance of the program. There were two reasons for this. *First*, there were fewer inspection visits conducted during the time period of the program than were anticipated. Whereas the normal schedule of MSET had been to conduct approximately one inspection a month, during this time only three such visits were conducted due to higher priority requirements. *Second*, there apparently was not sufficient extra time available during the evaluation trips to permit the administration of the new performance tests. Most of the substantive equipment tests, such as troubleshooting or adjustment, require from one to two hours each to conduct. Unless such tests are part of the primary evaluation, such blocks of time are hard to come by. The tests also require a number of supporting elements such as faulted parts and standard testing devices to achieve the necessary consistency of test conditions.

These support problems combined with the time required to administer such tests, are typical of administrative problems that surface when a new concept is attempted for the first time. It is emphasized that all of these conditions are administrative hurdles. They in no way reduce the quality of the JTPT concept or the urgent requirement for the use of such tests. Ways must be found to overcome such administrative problems. The remainder of this section and the next section of this report are devoted to this objective.

Benefits Expected from Policy Modification

The following discussion is not intended to reflect adversely on the present work of the MAC MSET. There is no doubt that the personnel of these teams are doing a good job within the limits of their manpower and resources. The MSET evaluation is designed to insure that there are no major deficiencies and that the personnel *appear* to be competent in their jobs. There are, however, no strictly defined standards of performance or production in electronic repair shops today. The JTPT being tried out in this study provide a means for measuring performance and production according to strict standards. But a command decision would be needed to require the development and enforcement of strict standards. And the development of such standards for all avionics in MAC would require more resources than are presently available for the evaluative function.

The spectrum of equipments found in MAC shops are but a part of the total spectrum of equipments assigned to personnel holding AFSC 328X4 Air Force wide. So the holder of this AFSC is actually a subspecialist in a MAC squadron. Any further specialization within a MAC shop makes the technician a sub-subspecialist. The criterion referenced JTPT being tried out in this study are concerned only with the AN/APN-147 Doppler Radar and its associated computer the AN/ASN-35. *And* within a MAC squadron specialization on one or another aspect of a Doppler Radar is not uncommon.

Although many holders of AFSC 328X4 function as sub-subspecialists, each is officially supposed to be able to perform maintenance on several equipments in MAC. If any of these 328X4's are transferred to other commands, they will be faced with different mixes of equipment. This raises a question of what standards of production a man holding AFSC 328X4 should be expected to meet. It raises still more basic questions in regard to the realism of personnel assignment policies. But, in the opinion of the writers we will never be able to improve maintenance Air Force wide until we have strict performance standards at the maintenance squadron level. *The use of JTPT cannot resolve any of these policy questions but their use will certainly emphasize the requirement for finding workable answers to such questions.*

Assuming for the moment that strict standards of performance and production would be desirable, let us examine the implications. The JTPT would have to be broadened to include all equipments within a MAC squadron. The periodic use of these tests would quickly identify the personnel who are "bottlenecks" in the production process. They would also provide *practical diagnosis* in what areas those personnel were weak; i.e., checkout, alignment, troubleshooting, and use of special or general test equipment. This diagnosis would provide the basis for command action. It would provide specifics. And specifics are needed to accomplish effective corrective actions. Command action would be required to enforce correction of specifics, but it would not be the general type of action that says "shape up" without also indicating the specifics of how.

Under present manpower and money restraints it may be impossible to develop JTPT for each of the large number of equipment specific tasks such as checkout, align, adjust, calibrate, remove and replace, and troubleshoot. But the limited number the JTPT on the use of general test equipments and on soldering have broad applications for most electronic technicians. In the opinion of the writers the development and enforcement of performance standards for the general test equipment spectrum of activities and for soldering are well within the current manpower limitations of a command like MAC. The enforcement aspect would, of course, require some change in MSET policy. A block of time for JTPT on the use of test equipments and on soldering would have to be scheduled for each team visit. In addition, a limited number of technicians would have to be diverted from their regular duties during each MSET visit in order to take these tests.

SECTION VI. APPLICATION CONSIDERATIONS AND SUGGESTIONS

The Department of Defense as well as industry *may be* forced into using criterion referenced tests before adequate consideration has been given to their developmental technology and their effective introduction and utilization in the training and work environments. Serious consideration must be given to these matters or a great deal of money and time will be spent uselessly before effective criterion referenced testing systems become a reality. The previous sections of this report have presented a developmental technology for criterion refernced tests for electronic maintenance.

The purpose of this section is to suggest approaches for accomplishing the introduction and effective utilization of such tests. Although aimed primarily at criterion referenced JTPT for electronic maintenance, much of what is presented also will be applicable to the measurement of job success in other areas of the world of work. The section begins with a statement of a number of objections to the use of JTPT, followed by a discussion of a number of topics which in the writers' opinion are closely related to the introduction and utilization of such tests. This is followed by some specific suggestions for the introduction of such tests into the Air Force work environment and into training. Some suggestions, also, are made concerning future research and development considerations.

Objections

When compared to the cost of paper and pencil objective tests, criterion referenced JTPT are more expensive to develop in terms of time, personnel and equipment both *in the field* and *in training*. And there is no doubt that JTPT do cost more to administer than paper and pencil tests, especially in the formal training situation even if they are administered by classroom or shop instructors. When the administration of such tests are assigned to the classroom or shop instructors, many times they do not find the time to administer them properly. When they are administered properly by a special unit (as in Air Training

Command checkrooms) they are even more expensive. Such a unit usually requires additional personnel and equipment. When administered by supervisors of a maintenance unit, less time is available for these supervisors' other activities.

A corollary to the first objection is that when job performance tests are given in the *formal training* situation they emphasize the requirement for sufficient equipment in the shops or laboratory. The usual result is a requirement for more equipment. If students are to be tested on job tasks, they must have sufficient opportunity to practice these tasks. This added practice on school equipment usually results in a requirement for more maintenance personnel. [The writers do not believe this latter requirement to be legitimate since the students and the instructors should be able to maintain their own equipment.] The added practice also causes the equipment to wear out faster.

The administration of criterion referenced JTPT results in scores having no variance against which to standardize aptitude tests. If administered against a go, no-go standard, criterion referenced tests by definition result in no continuum of test scores from subject to subject, much less a normal distribution of test scores. The result is two groups of subjects – *one* including those who can accomplish the task under test and *the other* including those who cannot. Such go, no-go scores cannot be handled by parametic statistical procedures traditionally used to standardize aptitude tests.

Some test and measurement psychologists prefer to use single factor statistical procedures when standardizing aptitude tests. JTPT such as the ones developed for this project are not single factor tests. Such tests to be truly representative of the maintenance jobs must include many factors; and to be meaningful, their reported results must reflect many factors meaningfully.

Application Considerations

There are a number of factors concerning or closely related to JTPT that have been considered in the preparation of the suggestions and recommendations for the implementation and use of JTPT. These factors are discussed in the following paragraphs. The writers also believe that these paragraphs provide some necessary background information for anyone considering the recommendations of this document.

Disregard for Empirical Validity

It should be noted that most of the objections ignore the fact that paper and pencil objective tests are not empirically *valid* measures of job ability. The fact that they are given, the fact that great confidence is placed in their results by most of their users and the fact that many important and expensive personnel decisions are based on their results, indicate that the validity of these such tests is seldom questioned. Many of the reasons given for using paper and pencil tests are based on administrative convenience totally disregarding empirical validity. Lyman (1971) has indicated that "Almost anything else can be forgiven if the test has very high (empirical) validity." The writers of this report are convinced that the current disregard of empirical validity in field and training situations would be unforgivable if the people involved really understood how invalid their current testing practices really are. No matter how cheaply paper and pencil job knowledge tests can be prepared or how easily they can be administered, such tests are not a bargain. Their results are often meaningless in terms of ability to perform maintenance tasks. AFHRL-TR-74-57(I) contains a detailed discussion of criteria and validity.

The writers, also, are aware of the fact that many current personnel and training systems are built around paper and pencil testing practice. To change such systems suddenly could be disastrous. What we recommend is an orderly modification of the current training and personnel systems. We purpose that JTPT be introduced so that the greatest improvement in maintenance efficiency can be obtained with the least disruption of our training and personnel procedures. *But* if Air Force is to have more efficient maintenance and formal training for maintenance, it is extremely important that the Air Force obtain *hard data* on how well maintenance men can actually perform the key tasks of their jobs. All available hard data would indicate that *maintenance* both in and out of the Air Force, although sometime effective, is very inefficient.

Part of this inefficiency results from many Americans having undue faith in written tests. An example is cited from the civilian world of maintenance. Certification of auto mechanics has recently received considerable attention. Such certification is based on the ability of the test subjects to pass a series of *job knowledge tests* on such subjects as engine repair, engine tune up and brake repair. What research tells us about such tests would indicate that the empirical relationship between the mechanics' success on this series of tests and their ability to actually perform these job activities is not very high. Little reliance can be placed in certification of maintenance proficiency which is based on scores obtained from paper and pencil job knowledge tests. *But* some garages require all of their mechanics to be certified.

Proficiency

For efficient operation, the acquiring of and maintenance of proficiency to perform the key tasks of their jobs are just as important for the maintenance personnel as it is for pilot personnel. As we all know, the Air Force as well as commercial airlines, have developed very extensive systems for insuring that their pilots have a high level of proficiency on the key job tasks before they are placed on-the-job, and for insuring the maintenance of their proficiency once they are on the job. Although the command maintenance standardization teams are a small step in this direction, there are no comparable testing systems for maintenance men. The standardization teams in their present stage of development do not insure that each maintenance man has obtained a prescribed level of proficiency in the performance of the key tasks of his job.

Just because a man works on a job daily does not insure that he is maintaining his proficiency on important job activities. An example, in the case of the pilot is instrument flying. It is certainly important that a pilot have a high level of proficiency in this area of his job. *But* it is highly possible that he could fly for months without having to rely solely on his instruments. As a result, when faced with a bad weather situation, he would not be able to perform, even though he had adequate proficiency at some time in the past. In a real sense, the electronic maintenance man is "flying on instruments" most of the time; that is, he must use his test equipment to determine what the electrons are doing since he cannot see them. Yet most maintenance men have never been required to take test equipment job performance tests. No one really knows (including themselves) how well or how poorly they can operate these instruments. Even if a technician had demonstrated at one time that he could use all the capabilities of his oscilloscope, there are some important capabilities of this instrument which he uses infrequently on his particular job. He usually cannot maintain a high level of proficiency on this instrument unless he receives proficiency practice in its use. Just as with the pilot's instruments, if the maintenance man was tested periodically on all the important uses of his oscilloscope, he would be motivated to maintain his proficiency.

Proficiency and Visibility. It would seem that those occupations or activities which are most visible are those in which a high level of demonstrated proficiency are demanded. And where a high level of performance is demanded, formal performance tests in some form are given to insure an adequate level. For example, we all see people drive automobiles. Most states now administer "a behind the wheel" performance test before issuing an individual a driver's license. Some states require a periodic retest after a person reaches a certain age. States and local governmental units have traffic control programs that monitor people's driving, which in a sense is a performance test on certain aspects of driving. As mentioned before, the Air Force and commercial airlines have very extensive job performance testing programs both in training and after job assignment. These tests ascertain that the pilot has the necessary proficiency upon initial placement and to insure that he maintains such proficiency while assigned to the job. Air Force band members who constantly are on exhibit to the public, must pass a performance test on two instruments in order to qualify in their AFSC. Sports are another area in which people are judged on their performance. A professional football player is not hired or given a pay increase on the basis of his ability to pass a written examination on football. All of the mentioned occupations are highly visible.

On the other hand, very few mechanics are ever required to demonstrate their ability to maintain an auto on a job performance test. And they repair most of the cars that are being operated by licensed drivers. As mentioned earlier, there is a national certification program, but this certification program for auto mechanics is based on a series of paper and pencil tests – not on demonstrated ability to actually perform maintenance tasks. And the public generally is not permitted to see the auto mechanic working. As far as Air Force maintenance specialists are concerned, they are qualified on paper and pencil job knowledge tests (Specialty Knowledge Tests). (Not like band members whose SKT is a performance test.) The civilian airlines have a much tighter system of certification. An aircraft engine or airframe mechanic must pass both a written and a performance test to be certified by the Federal Aviation Administration (FAA). *But* once he has his certificate, he is not given periodic performance tests to ascertain that he has maintained his proficiency. The FAA certification of electronic maintenance men is similar to the Air Force SKT where no performance tests are required.

JTPT on the Use of Test Equipment. One of the expected benefits from the use of JTPT in the Air Force training and maintenance systems will be the improvement of maintenance. *When implementing a technology it is always desirable to start with an area that effects the greatest improvement with the least expenditure of effort.* For many reasons, performance tests concerning general test equipment would be an excellent vehicles for effecting such an improvement.

1. **The uses of such test equipments are key maintenance activities.** An examination of the dependencies among maintenance tasks indicated in Table 1 and in the profile presented in Figure 10 indicates that *the ability to perform most maintenance tasks requires the ability to use such test equipments.* If a maintenance technician cannot use his test equipments well, he certainly cannot perform dependent maintenance activities well. This especially is true of the oscilloscope and the voltohmmeter (VOM). For example, if an electronic maintenance technician cannot properly operate and interpret his oscilloscope or VOM, he can read troubles into his prime equipment that are not there.

2. **Such test equipments have general applicability across the entire range of electronic equipments and are used by all personnel possessing electronic maintenance AFSCs.** Stated differently the use of test equipment is a "g" factor common to all maintenance activity. As a result, the administration of a rather limited number of JTPT concerning the use of test equipment should, thus, result in a general improvement in the quality of maintenance.

3. **Based on available information few electronic technicians are expert in the use of the oscilloscope or the VOM.** A comprehensive Navy study by Anderson (1962) covered 415 Navy Electronic Technicians from the Pacific Fleet. A smaller Air Force study covered thirty "5" and "7" personnel (Foley, 1969). Both indicated that technicians were not able to use their equipment effectively. The results of these two studies are summarized from Foley (1969) in Table 4.

Table 4. **Percent of Correct Measurements for Each Type of Test Equipment in a Navy Study (Anderson, 1962) and an Air Force Study (Foley, 1969)**

Type of Test Equipment	Number of Activities	Percent of Correct Measurements	
		Navy N = 415*	Air Force N = 30**
Multimeter (VOM)	7	73.5	51.7
Vacuum Tube Voltmeter (VTVM)	4	63.0	76.6
Signal Generator	4	57.1	64.3
Oscilloscope	6	32.0	

*Sample included 68 chiefs, 55 first class petty officers (POs, 66 second class POs, 131 third class POs, and 95 seamen.

**Sample included 5 and 7 level, mostly staff sergeants and technical sergeants.

As mentioned earlier in this report, during the development and tryout of the test equipment JTPT for this project, a great amountsof difficulty was experienced when trying to find Air Force technicians who were expert in the uses of the 545B Tektronix Oscilloscope. This is still more evidence supporting the contention that maintenance technicians generally are not proficient in using test equipments. Large scale administration of JTPT on the uses of common test equipment both in training and in the field would give us *much needed*, up-to-date hard data on how well electronic personnel can use their test equipments.

4. **Considering the large number of prime electronic systems now assigned to each electronic maintenance AFSC, it is impossible for a maintenance man to have an in-depth knowledge of each system. But** if he can operate his test equipment with a high degree of proficiency and he has confidence in his ability, he can manage to perform a great deal of maintenance on an unfamiliar system. On the other hand, if he is unsure of himself on both his test equipment and his prime equipment, it is extremely difficult for him to function. So he is faced with either doing nothing or with removing and replacing components until he gets the system to operate.

5. **A common complaint of designers and managers of electronic systems is that systems do not function with the sensitivity for which they were designed to operate.** The writers believe that a major cause of this problem is that maintenance technicians are not able to properly adjust and calibrate these

systems due **to their limited ability to use test equipment, especially the oscilloscope**. The writers also believe that there has been a great tendency on the part of many electronic maintenance technicians to avoid the use of the oscilloscope because they do not know how to use this instrument and as a result are afraid of it.

Use of Part Task Trainers and Simulators. One of the reasons frequently sighted for not utilizing JTPT in training is the added equipment required for practice and testing. As soon as performance tests are given, the amount of "hands on" practice always increases. This is probably one of the reasons that such tests are not found in great numbers in Air Training Command. With only a limited number of equipments and a large number of students, the practice of checkout procedures alone soon wears out components on equipments which are not designed for such constant adjustment. There are training innovations that can ease equipment wear and usage. Some of these include:

1. **Photographic trainers for practicing checkout procedures, and for interpreting VOM, Vacuum Tube Voltmeter (VTVM), and oscilloscope displays.** Unpublished work of AFHRL has indicated that subjects can learn check out procedures using full scale photographic trainers as well as they can using the actual equipments.

2. **Special inexpensively built signal sources that cover the range of capabilities of VOM, VTVM, and oscilloscopes.** (Sample of such signal generators have been developed for this project.) Such signal sources make it possible for students and technicians to practice all of the capabilities of these test instruments without tying up prime equipments.

3. **Inexpensive part-task trainers for practicing many of the maintenance activities.** For example, alignment trainers could be constructed that would provide practice on many alignment behaviors.

4. **Full-task simulators for some jobs.** Full task simulators can be developed for such tasks as the flight line checkout and troubleshooting to the blackbox level for many electronic subsystem found on aircraft. An example is found in the trainer developed for the Learned Centered Training Project (Rifkin, Pieper, Folley, & Valverde, 1969).

In-Depth Training on One System

Due to the large number of electronic systems assigned to most electronic maintenance AFSC, it has been considered impossible to give in-depth formal training on all systems. The current formal training solution to this situation has been to expose all airmen entering all electronic AFSCs to a common electronic fundamentals course. This common training is followed by "sets" training on several typical systems found in the specific AFSC to which the airmen is assigned. The "sets" training is usually of the orientation variety in which the student receives very little "hands on" training. As a result, students, although exposed to several systems, receive no in-depth "hands on" training on any one system. What "hands on" experience each airman receives is after he is in place in his first job. The result is that he may never receive any in-depth training and practice in many key maintenance tasks even on that job. At the present time, it would be impossible to administer a complete battery of JTPT such as those developed for this project for any system during formal training because students have not been trained to perform many of the tasks covered by the JTPT battery. Many maintenance technicians will not learn to perform many maintenance tasks with a high degree of proficiency unless they know they are going to have to demonstrate their proficiency on a formal performance test.

Considering the current structure of the personnel system with regard to maintenance, the most effective but also most costly training system in terms of time, money and equipment, would be to provide in-depth "hands on" training supported by JTPT for every system on which a technician is required to perform maintenance. Considering the large number of systems in the Air Force inventory, such a solution is out of the question. But in the opinion of the writers indepth "sets" training on one system would provide a solution that would insure improved demonstrated maintenance performance during formal training.

There are research results that would indicate that "hands on" in-depth training on one typical equipment is more effective than orientations on several system (Shriver, 1960; Shriver, Fink, & Trexler, 1964). In this FORECAST Project, the students were given comprehensive JTPT on the one system on which they were trained to insure that they could perform all the maintenance tasks on that one system. It was found that these students could perform maintenance tasks successfully on similar equipments with a limited amount of orientation. Students, who had received orientation on a number of equipments, without in-depth training on any one equipment, were not able to perform adequately on any equipment. These findings would indicate that many complex maintenance behaviors, once learned well for one system, can be transferred to another system. In the opinion of the writers such transfer can be facilitated by training programs which are designed to teach transfer. For example, maintenance procedures can be learned in-depth for one system followed by an orientation on a second system which points out the maintenance similarities between the two systems. The technician will learn to look for such similarities in unfamiliar systems.

Individual vs Group Administration of JTPT

This subject was discussed earlier in this report with respect to the utilization of profiles. Further discussion is included here as a possible solution to the current application barriers outlined previously. In the opinion of the writers, if management considers that the administration of JTPT on an individual basis is unfeasible with respect to expense and time, their administration on a group basis, using systematic sampling techniques, should be given serious consideration. A great deal can be learned about the maintenance ability of a given maintenance unit or the relative effectiveness of abilities between units using such techniques. Technical training job effectiveness can be measured by applying the same type of sampling techniques to the members of each graduating class. As stated before, sampling could be across individuals, by giving selected representative individuals from each group the entire battery of tests. Sampling could be across classes of tasks; that is, give all members of one group a selected class of tests such as alignment and the next group tests concerning another class of tasks such as checkout, etc. Another mix could be to select one test such as the oscilloscope test and administer it to a limited number of subjects from each group for an extended period of time. This last suggestion would be ideal if it was decided to concentrate on use of test equipment to the exclusion of other performance tests. Many other sampling mixes could be suggested. However, whatever sampling scheme is utilized there is no doubt, in the opinion of the writers, that valuable hard data would be obtained about quality of maintenance for manager and trainers. In addition, the quality of maintenance would improve in the areas of test coverage.

Symbolic Substitute Test. A somewhat promising adjunct to actual JTPT are symbolic substitutes. Symbolic substitute tests are tests that require the subject to perform in a manner similar to the real world of maintenance, but not using actual hardware. Such tests may use pictorial or inexpensive whole or part-task simulators. They are not traditional job knowledge tests. A follow on research project supported by AFHRL has developed some symbolic substitute tests. The development and limited tryout of these tests are reported in **AFHRL-TR-74-57(III)**. They are mentioned here only because they have implications concerning the introduction of JTPT to both the Air Force training and field environments. For example, such tests if successful, might be used to supplement performance tests in troubleshooting. An individual subject might be given only one or two troubleshooting problems on actual equipment but a large number of such problems by symbolic substitution. *However, such tests should not be used until it can be demonstrated that they have high empirical validity.*

Prediction of Training and Job Success. For over twenty years the Air Force has had a selection system that has included the use of prediction or aptitude tests. Personnel selected using these tests are successful when current training procedures are used. These aptitude tests have been standardized on the basis of the final graduating scores of students. Such scores are heavily weighted with the results of paper and pencil objective tests scores. These end-of-course scores form a very convenient basis for standardizing aptitude since they usually produce a wide range of variance.

Selection tests of this type have recently been subjected to a great deal of criticism because they have not selected personnel of different ethnic groups equally. It has been demonstrated that many of the personnel who have been rejected by this system can be taught to successfully perform the tasks of the actual job when job oriented training procedures are used. The measurement of training success under these conditions is based on the criterion of job success rather than on the criterion of paper and pencil tests.

Job criterion referenced tests such as JTPT would provide a much more realistic basis for standardizing aptitude or selection tests for training than the current type of school scores. However, go, no-go scores in themselves provide no variance for the current standardizing procedures. The writers believe that there are several possible solutions to this situation. One solution would be to use the *time in training* required for individual students to reach criterion as the norm for standardizing such aptitude tests. Under proper conditions, such time scores would probably provide scores with sufficient variance to apply current standardizing procedures. More modern training technologies encourage individually paced training. If individual pacing were applied in job oriented "sets" training, time to criterion should produce a sufficient amount of empirically valid variance. (This of course assumes that paper and pencil aptitude test items can be found that would discriminate on the basis of this source of variance.) The traditional "locked step" training practices, which tend to force most students to complete training in a standard amount of time, would not produce the necessary variance.

Another possible solution would be to use the number of attempts an individual student requires before he successfully reaches criterion on each JTPT that he is given during training. (This could be data gathered either during formal training or during on-the-job training.) Such a system would result in each class of job activity providing a separate factor against which to standardize aptitude test items. To use this approach, test psychologists may have to shift to non-parametric statistical procedures to determine the predictiveness of each aptitude test item in relation to the number of attempts on each JTPT.

Suggested Applications

Need for Hard Data Concerning the Performance of Maintenance

The Air Force is authorized approximately 180,000 maintenance men. More than 80 percent of these airmen will spend only four years with the Air Force. Most of the first enlistment airmen receive rather extensive formal technical training as well as on-the-job training. As a result, the support of this maintenance personnel system is extremely costly. The Air Force's large investment in initial training is soon lost. Yet, there is no bank of hard data, even on a sampling basis, concerning how job effective and how job relevant this extensive training exercise is. And there is no bank of hard data on how well maintenance men can perform the tasks of their jobs. What limited hard data, which have been obtained from time to time, would indicate that neither training nor job performance are too effective. But when such data are presented the often heard reaction is "it can't be that bad."

The writers have reviewed the limited hard data, and in addition, have observed maintenance in many field settings. They are of the considered opinion that "it is that bad" and that the Air Force maintenance establishment as well as many civilian maintenance establishments are getting very inefficient results from their maintenance training dollars. The only way we can determine how well individuals or units can perform key maintenance tasks is to administer well designed JTPT to airmen graduating from training and to airmen on the job.

It is often said that the Air Force does not have the time nor the money for the development and administration of JTPT for all of the hardware systems in the Air Force. This may be true. But even a few well selected tests will give Air Force managers much better information than they now possess. In the following paragraphs some suggestions are made as to how the Air Force can start gathering such data on a rather modest basis for electronic maintenance, and at the same time develop better tools for measuring the true efficiency of training and maintenance.

Suggested Uses of JTPT in Maintenance Squadrons

Individual maintenance performance is a *key* factor in determining how *efficiently* the total maintenance of that squadron is performed. Maintenance can be performed effectively without being performed efficiently. Current evaluation procedures do tell us if maintenance is performed effectively; but as stated earlier, they do not provide specifics concerning the efficiency of individuals. Until such *specifics* are available, no effective corrective action can be taken to improve the overall efficiency of a maintenance squadron. And no great improvement in the overall efficiency of maintenance in the Air Force can be obtained until more specific hard data are available based on the efficiency of individual squadron maintenance personnel. Until such hard data are available maintenance organizations cannot give specific feedback to their related training organizations as to their real training requirements. The Maintenance Standardization Team of each command is an existing organization that can be used for obtaining at least some of the necessary specific data. A gradual modification of their current procedures is suggested in the following paragraphs.

JTPT on Use of Common Test Equipments. Since common electronic test equipment is used by all electronic technicians, serious consideration should be given to systematic administration of these JTPT.

For the first few visits to each maintenance squadron, these tests could be administered to maintenance technicians identified by each squadron as proficient in the use of test equipment. Later such tests could be administered to technicians selected at random by the standardization team. The idea being that if the squadron supervisors expected such tests they would insure that all their technicians would be proficient in their use. The writers are of the opinion that the maintenance of a high proficiency by all electronic technicians in the use of common test equipment would greatly improve the quality of maintenance. Such tests would also provide common measures to compare squadron effectiveness.

The Injection of JTPT on Prime Equipments into the Maintenance System. After JTPT on test equipment are implemented as suggested above, a *second step* would be to insert test items of equipment (from the JTPT) for repair in the regular work load of the unit. These items would be assigned for repair on a regular basis and would not be identified as special test items. Performance on these items would be measured by a TA according to the standard conditions of the JTPT. This action would be similar to that of driving a car with a known standard fault into a number of repair stations to obtain estimates of damage and cost to repair. The progress of a standard item through the unit could be tracked to determine the number of parts replaced, number and level of man-hours expended and quality of repairs made. This would provide base line performance data with standard times by which performance across units could be compared and standardized.

The *third step* would be to produce similar faulted units for other systems within the MAC squadron, and finally for all the equipments assigned to the AFSC. These items would serve as the standard reference for work in units. The way in which they were handled, on a routine basis, would serve as both a standard and as a diagnosis of what specific corrective actions needed to be taken to bring units up to specific standards and keep them there.

These steps represent a gradual implementation of a change in policy. Under the present policy, technicians are expected to "do their best," and the MSET inspections are used to determine that this is being done. The alternative provided by the criterion referenced JTPT is that men would be expected to meet a standard that is above their present "best." By improving performances, through diagnosis of specific weaknesses, the "best" performance of technicians would become better.

Suggestions for Expanding the Use of JTPT in Training

For the last five or six years there has been a movement in Air Training Command to increase the use of JTPT in technical training. *Such usage in itself will help improve the job skills of students since instructors teach and students learn whatever is emphasized in the testing program. The expansion of this JTPT Program should be encouraged for this reason alone.* However, the scores from such tests are combined in some manner with the many paper and pencil test scores administered during training. So when and airmen graduates, we really know nothing concerning his success in job like activities during training.

Tests on Use of Test Equipment. As discussed earlier, standard tests on the use of common test equipments especially on the oscilloscope, the VOM, and the VTVM offer very effective vehicles for insuring a high degree of proficiency in the common activities of all electronic maintenance jobs. One set of common tests could be used for all electronic maintenance students. Examples of such tests have already been developed for this effort.

Students cannot be expected to pass these tests on a "go, no go" basis without sufficient "hands on" practice. Students cannot be expected to develop a high degree of proficiency in the use of their test equipments by watching someone else use them or by using them from time to time as an incidental aspect of their "sets" training. A common task oriented block of programmed instruction could be easily developed for this purpose. There is already a model for such a program for the Tektronix 545 Oscilloscope (Woods, Trudo, & Pieper, 1966). But more practice exercises would have to be added to that program.

A profile of each student's success should be maintained and no student should be permitted to graduate until he has demonstrated that he can perform all of the required functions of these equipments. Such a test should be given to students upon completing the test equipment block of instruction. Immediately before graduation, these tests should be administered to at least a sample of students to ascertain how well they have maintained their proficiency.

The use of these common JTPT would provide an opportunity for teaching many instructors how to administer JTPT in an objective manner.

Tests on Checkout Procedures. Checkout procedures are important activities which performed for all electronic equipment. The writers suggest that each graduate should be able to demonstrate high proficiency in the checkout procedures on one or two typical equipments for his AFSC in both the organizational and intermediate maintenance enviornoments. This skill would then be more easily transferred to other equipments in his AFSC. Since such procedures can be *practiced* on inexpensive full sized photographic mock-ups, JTPT on checkout procedures could be added to "sets" training without increasing wear on the actual equipment.

Suggestions for Research and Development

Development of a Model Job Oriented Training Program. Students given the current orientation type of "sets" training would probably be unable to pass a battery of JTPT similar to those developed for this project. It is suggested that a model self-paced training program be developed for one broad based electronic AFSC. One typical electronic systems maintain by this AFSC should be selected for in-depth training and a battery of JTPT should be developed for that system. The training program should provide sufficient practice on the performance of the typical tasks and should reflect the dependency reflected in the scoring profile in the ordering of such practice.

This training should be followed by orientation training on a similar typical system, followed by the administration of a battery of performance tests. Successful performance would support the hypothesis that in-depth training on one system is transferred to similar equipments.

Development of Aptitude Tests Based on Criterion Referenced Tests. Aptitude tests should be developed using the data available from the training and testing on common test equipment and from the suggested model course as the base for standardization.

Reporting of Maintenance Research Results. In the past, a great deal of confusion has developed concerning the scope of coverage of various maintenance research projects concerning both training and measurement. A diagram, similar to that shown in Figure 1, is recommended for inclusion in reports of such work so that the reader can easily ascertain the scope of the work.

Needed Research and Development Required on Other Areas of Measurement. No in-depth developmental projects of criterion referenced JTPT for typical *mechanical* hardware have been reported to date. A typical jet engine is recommended as the test bed for such a development. Work in this area is greatly needed if maintenance of engines is to become less expensive.

SECTION VII. SUMMARY AND CONCLUSIONS

This report describes the development and tryout of a Job Task Performance Test (JTPT) System for Electronic Maintenance Technicians. In addition, a number of other factors related to the use of JTPT are discussed in the report. The summary and conclusion statements are listed under two appropriate subheadings – **Development and Tryout of JTPT** and **Other Relevant Factors Concerning the Development and Use of JTPT.**

Development and Tryout of JTPT

1. The main thrust of this effort was on the development of the criterion referenced Job Task Performance Tests. A comprehensive classification of tasks of electronic maintenance jobs already existed. Representative tasks were selected from each of these classes. The requirement to perform a task become a test of the test battery. A test was developed for each selected task. Every effort was made to insure that each test required the test subject to perform the task being tested in the same manner as he would on his actual job. These developmental actions were taken to make these tests as near to the ultimate criterion, the job, as possible. On these bases the tests are assumed to be empirically valid by definition and no further proof of their validity is possible or necessary. It is realized that all aspects of job performance are not reflected in these tests. The ability to perform the job tasks required by the tests is an absolutely necessary aspect of the maintenance job, but it is not necessarily sufficient for complete job performance.

2. A total of 48 Job Task Performance Tests (JTPT) was developed covering typical organizational and intermediate maintenance activities for electronic systems. The activities covered include checkout; align, adjust and calibrate; remove and replace; troubleshooting; soldering; and use of test equipment.

3. JTPT were developed for typical organizational and intermediate maintenance activities for electronic subsystems. JTPT were not developed for depot maintenance for electronic systems. No JTPT were developed for the maintenance of mechanical systems such as engines.

4. The developed JTPT, together with the accompanying administrators' manual and training program for Air Force administrators, are intended as a model system for future developments of job task criterion referenced tests for electronic maintenance. A large number of the tests are system specific for the Doppler Radar, the AN/APN-147 and its computer AN/ASN-35. However, the soldering tests and the tests on use of general test equipment have applicability across systems.

5. The criterion of success for any test problem is the generation of an acceptable *product* without assistance of another person. This is a go, no-go criterion. Process may be used for diagnostic purposes but no credit is given for accomplishing part of the problem correctly. If *time* is a critical factor for the particular task (such as checkout on the flight line), it will be included as part of the go, no-go criterion for that particular task. Otherwise, the subject is required to complete the problem in a reasonable time.

6. The activities tested are not mutually exclusive. For example, the troubleshooting activity can include all the other activities. The activities can be arranged in a four level hierachy of inclusiveness as follows: (1) checkout, remove and replace, and soldering activities; (2) use of general and special test equipment; (3) align, adjust, and calibrate activities; (4) troubleshooting.

7. This hierachy of dependencies among activities made possible the development of a diagnostic profile for reporting test results in terms of the "go, no-go" criterion (Figures 10 and 11). A further application of this hierarchy of dependencies requires that an individual demonstrate proficiency in first and second levels of the hierachy before he is permitted to be tested on the third and fourth levels. For example, a subject must demonstrate his ability to use general and special test equipment without error before being allowed to take the align, adjust, or calibrate tests. He should not be permitted to take the troubleshooting tests until he has passed the align, adjust, and calibrate tests. This hierachy of maintenance activities also has similar implications concerning the order in which a newly assigned apprentice or technician should be permitted to perform the maintenance tasks on an unfamiliar equipment. In addition, it has implications as to the order in which JTPT should be introduced into the field and training situations.

8. *No attempt should be made to combine the results indicated on this JTPT profile into a single numerical score – such a score would be meaningless in terms of how job successful or job ready an individual is. And certainly no attempt should be made to combine the results obtained from JTPT with scores obtained from paper and pencil theory and job knowledge tests.*

9. The go, no-go type of scores resulting from criterion referenced tests such as JTPT provides *no variance* from individual to individual, except the dichotomy made up of the group of individuals which achieves criterion and the group that does not. Current procedures which standardize aptitude tests against a single final school score for each individual would also have to be modified.

10. The JTPT were designed as model criterion referenced tests for use in field maintenance units; for use in formal and on-the-job training; and for use as criterion tests in research projects involving maintenance. Since field maintenance units are responsible for the performance of the activities covered by the UTPT, such units were deemed to be the most desirable situations for the initial tryout of the JTPT system. Another consideration was to reduce as much as possible the "exceptional" nature of the testing activity generally associated with training programs or research projects. It also was desired that the tests be administered by Air Force maintenance personnel. The Military Airlift Command (MAC) agreed that personnel of its Maintenance Standardization Evaluation Team (MSET) be trained as test administrators and that tests be administered in the MAC maintenance units during evaluation visits.

11. Since the tests were developed to be empirically valid, the main objective of their tryout was to ascertain that the tests were administrable. A secondary objective was included for their tryout, that of obtaining a needed bank of hard data concerning how well a large sample of Air Force electronic technicians could perform key tasks of their jobs. Only the first objective of the planned tryout was achieved.

12. During and after development each of these JTPT was administered at least seven times to insure its administrative feasibility. In addition, the tryout of the JTPT system indicated that Air Force maintenance technicians can be successfully trained as administrators and they are able to administer tests to Air Force maintenance personnel.

13. The secondary objective of the planned tryout was not achieved because it was not possible for the MAC Maintenance Standardization Team to administer as many of those tests as had been anticipated. Several factors contributed to this result. The standardization teams made fewer evaluation visits than originally planned during the tryout period. In addition, the team operates on a basis of minimum interference with the operations of the field maintenance unit being evaluated. Since this policy could not be waived during the tryout period, it was agreed that the team would give such performance tests as time permitted upon completion of their regular evaluation. As a result there was little time left for these formal performance tests.

14. Currently there are no strictly defined standards of performance for the maintenance of electronic equipments. *And* there seems to be no "felt need" for such standards at the present time. The current MSET evaluations are designed to insure that there are no major deficiencies and that personnel *appear* to be competent in their jobs. Until strictly defined standards are developed and enforced no great improvements in maintenance efficiency can be expected. Such a program would require several man-years of effort to develop and implement, but some steps in this direction could be taken within present manpower limitations, such as, the administration of the general test equipment JTPT.

Other Relevant Factors Concerning the Development and Use of JTPT

15. High empirical validity or criterion-related validity is the most important single attribute required of job-related tests. JTPT are criterion based tests and have high empirical validity by definition. All available research studies indicate that most paper and pencil job knowledge tests and theory tests have extremely *low* empirical validity. *But* many Americans accept the validity of such paper and pencil tests without question.

16. Paper and pencil job knowledge tests are more easily developed and administered than JTPT. They require no equipment. They usually require less time to administer. *But they do not measure how well individuals can perform the tasks of the maintenance jobs*; and maintenance men are paid to perform maintenance tasks. Such job knowledge tests are no bargain, no matter how cheaply they can be developed or how conveniently and easily they can be administered.

17. Current personnel and training systems are built around paper and pencil testing practices. To change such systems suddenly could result in disaster. *But* an orderly modification of training and testing practice is possible.

18. For efficient Air Force operation, the acquisition of and maintenance of *proficiency* for performing the key tasks of their jobs is just as important for maintenance personnel as it is for pilot personnel. The Air Force, as well as commercial airlines, have developed very extensive systems for insuring that their pilots have a high level of proficiency on the key tasks of their jobs before they are placed on the job, and for insuring the maintenance of such proficiency once they are on the job. Although the command standardization teams are a small step in this direction, there are no comparable testing systems for maintenance men.

19. Soldering and the use of general test equipment (such as the oscilloscope, the Voltohmmeter (VOM), the Vacuum Tube Voltmeter (VTVM), tube tester, and transister tester) are common activities performed by all electronic maintenance personnel. Available hard data indicates that many technicians do not have high proficiency in some of these activities. A common systematic training and testing program for insuring a high degree of proficiency in these activities would result in great benefit to the Air Force.

20. The administration of more JTPT would increase the amount of "hands on" practice by students and technicians. Excessive practice on in-place prime equipments can cause wear. The use of inexpensive equipment substitutes such as photographic trainers, part-task trainers, and inexpensive simulators can greatly reduce the requirement for practice on prime equipments.

21. Under the current Air Force personnel system, a person assigned to any electronic maintenance AFSC is responsible for the maintenance of a large variety of electronic systems. Initial training cannot possibly cover all such systems. However, in-depth "hands on" training, including performance testings on one typical electronic system, is probably more effective training for transfer than "hands off" orientations on many typical systems.

22. The administration of the entire battery of JTPT such as developed for this project requires a great amount of time. Under some circumstances, time does not permit complete testing. For situations such as end of training evaluations and evaluation of maintenance units, the systematic sampling across tasks and across individuals would provide valuable evaluative information – certainly much better than random unstructured observations.

SECTION VIII. RECOMMENDATIONS

1. There is *very little relationship* between *success* on paper and pencil job knowledge and theory tests, and *ability* to perform tasks of maintenance jobs. This information should be given wide publicity to Air Force people at all levels in maintenance, personnel, and training. The current confidence placed on the results of these paper and pencil tests is unjustified.

2. JTPT on the use of common test equipments and on soldering should become a scheduled and reported part of each command standardization team's evaluation of a maintenance squadron. Eventually, subjects for such tests should be selected at random from the electronic technicians assigned to each squadron being evaluated.

3. Each electronic technician should be required to demonstrate his proficiency in the use of general test equipment and in soldering on an annual basis, just as pilots must demonstrate their ability to fly on instruments.

4. Rather than attempting off line administration of equipment specific JTPT, the command standardization teams should inject "black boxes" with standardized faults into the normal equipment repair pipe line and observe the results. The diagnostic information obtained from such a modified administration of JTPT should be used for command action for improving personnel performance in specifically identified areas of weakness. Repeated applications of equivalent tests should be used to insure that performance is brought up to the specified standard across all units responsible for this equipment.

5. JTPT on the use of common test equipments and on soldering, together with appropriate programmed instruction packages requiring sufficient "hands on" practice, should be included in all formal Air Force electronic technician training programs. No student should be permitted to graduate from an electronic maintenance training program until he has successfully passed these JTPT;

6. The hypothesis, that "in depth," "hands on" training on one typical electronic system for an AFSC would be more effective for transfer of training than "hands off" orientation on many such systems, should be tested. For this purpose, a model training program should be developed which would include the following characteristics: (1) it should be developed for one typical equipment or system of a typical electronic AFSC; (2) its criteria of success should be a battery of JTPT such as those described in this report; (3) it should be self-paced and no one should be graduated until he successfully demonstrated criterion performance; (4) a profile such as the one described in this technical report should be used to report training success; (5) it should provide for a large number of "hands on" maintenance exercises; (6) the ordering of these training exercises should be based on the dependencies described in this report; and, (7) maximum use of inexpensive equipment substitutes; such as photographic trainers, part-task trainers, and inexpensive simulators, should be developed for and be used in this training program.

7. After a training program with the desired charateristics has been developed, exploratory work should be started on an aptitude testing program, which would predict job success based on success in this training program and on JTPT results from maintenance squadrons. The feasibility of such sources of variance as *time to complete training* and *number of attempts required to reach criterion on each JTPT* should be explored as well as the possible use of non-parametric statistical procedures.

8. A model JTPT system should be developed and tried out for *mechanical* systems. A typical jet engine is recommended as the test bed for such a development.

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APPENDIX A: A SAMPLE OF JOB TASK PERFORMANCE TEST (JTPT) MATERIALS

1. Test Subject Information Sheet
2. Test Subject Identification Sheet
3. Test SE_7 - Problem 5 - Oscilloscope Test
    - Subject's Instructions
    - Subject's Answer Sheet
4. Test TS-1 - Troubleshooting Test - 1
    - Subject's Instructions
    - Subject's Answer Sheet

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1. The test materials for all JTPT developed for this effort are provided in AFHRL-TR-74-57(II), Part II.

TEST SUBJECT INFORMATION SHEET

This series of tests is being conducted to determine job proficiency among electronics maintenance personnel. The tests cover the use of electronic test equipment, hand tool use, and equipment troubleshooting.

Testing will be conducted in your normal work areas. You will be given specific instructions as to the order in which you will take the tests.

This package contains all of the instructions and answer sheets for each test. As you are assigned to a test station, you will be told which set of instructions to use and how to proceed.

Some of the instructions are rather complex and may need to be read several times to gain full comprehension of what is expected of you. It will be well worthwhile for you to take the time and read the instructions carefully. If there is any question in your mind as to what you are required to do, feel free to ask the test administrator. It is also important that before you actually begin the test you know what answers are required.

You may direct requires for any technical data, test equipment and other support requirements to the test administrator. The test administrator will assist you with any problems that you may encounter.

Please complete the Identification Sheet on the next page and turn it in when requested.

Identification No.__________

IDENTIFICATION SHEET

NAME____

RANK______________________ SOCIAL SECURITY NO.______________

ORGANIZATION______________________________________

PRIMARY AFSC____________ TIME HELD_______ DUTY AFSC__________

____

DOES YOUR PRESENT JOB INCLUDE MAINTENANCE OF THE AN/APN-147-AN/ASN-35 SYSTEM? YES______ NO______

WHAT USAF SCHOOL COURSES HAVE YOU HAD?

COURSE	DATE	LOCATION

TEST SE7

PROBLEM 5, FORM 3

PROCEDURES:

a. Channel "A" on the oscilloscope will be used for this problem.

b. Ground the oscilloscope to the "Ground" connection indicated on the Waveform Generator Console.

c. Set the sweep to display seven pulse of the waveform present at Test Point 6710 on the Waveform Generator Console.

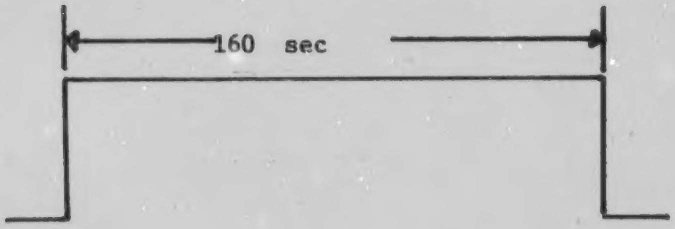
d. Utilize the delayed pulse feature to display the center pulse (4th positive going pulse from the left) in the center of the graticule.

e. Compare all of the resultant values of the waveform on the oscilloscope with the one shown below to determine if it is within tolerance of ± 10%.

f. Mark the appropriate answer box below to indicate whether the Test Point waveform is in or out of tolerance.

g. Record your selected scope control settings on the Oscilloscope Control Setting Answer Sheet.

h. Return your answer sheet to the Test Administrator to go to the next problem.



Within Tolerance ☐

Out of Tolerance ☐

TEST SE7

PROBLEM 5, FORM 3

OSCILLOSCOPE CONTROL SETTING ANSWER SHEET

CONTROL	SETTING
Trigger Mode (Time Base A)	
Horizontal Display	
DELAY Multiplier (Read-out)	
Stability (Time Base A)	
Time/CM (Time Base A)	
Time/CM (Time Base B)	

TEST INSTRUCTIONS

1. TEST

   TS-1

2. TIME ALLOTTED

   30 minutes

3. INSTRUCTIONS

   a. A problem in the Radar Set, AN/APN-147, makes the system function incorrectly. Troubleshoot and isolate the malfunction to the defective part. Use whatever techniques and equipment that are available to localize the problem.

   b. Radar inoperative - Malfunction is NOT an alignment or adjustment.

   c. DO NOT UNSOLDER ANY PART FROM THE CIRCUIT FOR ANY REASON.

   d. You can remove "plug-in" type parts such as tubes, crystals, relays, etc., and test on appropriate test equipment.

   e. If you suspect that a certain resistor, capacitor, transistor or other non plug-in item is defective, remove the module containing that part from its chassis. Ask the Test Administrator for a replacement module in which that part is good.

   f. If you decide a tube or other plug-in is defective, ask the Test Administrator for a good replacement.

   g. After you receive a serviceable part or module from the Test Administrator, replace the item and recheck the system.

   h. Complete your answer sheet as soon as you have identified the defective part.

TEST TS-1

ANSWER SHEET

A. What defective part did you find? Name part and schematic designation.

B. Check Test Equipment You Used for Troubleshooting

☐ Oscilloscope
☐ VOM
☐ VTVM
☐ Signal Generator
☐ Sweep Generator

☐ Frequency Meter
☐ Power Meter
☐ Spectrum Analyzer
☐ Distortion Indicator

☐ Tube Tester
☐ Transistor Checker
☐ Semiconductor Diode Tester
☐ Audio Oscillator

List any Specialized Test Equipment You Used for Troubleshooting.

APPENDIX B: JOB TASK PERFORMANCE TEST (JTPT) SCORING AND DIAGNOSTIC INFORMATION

Table B1. JTPT Scoring and Diagnostic Information

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
AL1	Subject makes an Antenna Synchro Alignment.	1	1	The Test Administrator (TA) evaluates whether or not the alignment was done correctly.	1	Subject Answer Sheet contains an equipment checklist and the subject places a check next to equipment that he used. This information may be reviewed and anlyzed.
AL2	Subject makes a 200-KC Bandpass Filter Alignment.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and anlyzed.
AL3	Subject makes 90-KC Bandpass Filter Alignment.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AL4	Subject makes a Computer Binary Division Ratio Alignment Check.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
AL5	Subject makes a Computer Resolver Bridge Balancing Alignment Check.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AL6	Subject makes Transmitter Synchros TX-501, TX-502, TX-503 Alignment Checks.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AL7	Subject makes a Control Transformer, CT-501 Alignment.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AL8	Subject makes a Control Transformer CT-301 Alignment.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

TEST CODE	TEST DESCRIPTION	SCORING SCHEMA				DIAGNOSTICS PROVIDED
		NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	
AL9	Subject makes a Transmitter Synchro, TX-302 Alignment.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AL10	Subject makes a Transmitter Synchro, TX-301 Alignment.	1	1	The TA evaluates whether or not the alignment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AD1	Subject makes a Transmitter Output Power Adjustment.	1	1	The TA evaluates whether or not the adjustment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AD2	Subject makes a Modulator Adjustment.	1	1	The TA evaluates whether or not the adjustment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AD3	Subject makes a Crystal Oscillator, V-6701A Adjustment.	1	1	The TA evaluates whether or not the adjustment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
AD4	Subject makes a second Balanced Modulator V-6709 Cathode Balance Adjustment.	1	1	The TA evaluates whether or not the adjustment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AD5	Subject makes a Phantastron Frequency Adjustment.	1	1	The TA evaluates whether or not the adjustment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
AD6	Subject makes a Sine-Cosine Potentiometer R-301 Adjustment.	1	1	The TA evaluates whether or not the adjustment was done correctly.	1	Equipment checklist completed by the subject may be reviewed and analyzed.
TS1	Subject locates, identifies and repairs a defective V-7207 (6080 WA) tube from Frequency Tracker Power Supply and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the replacement components reuested by the subject. Also the subject identifies on a checklist the test equipment he utilized.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

TEST CODE	TEST DESCRIPTION	SCORING SCHEMA				DIAGNOSTICS PROVIDED
		NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	
TS2	Subject locates, identifies, and replaces a defective L-8101 Coil in the Modulator Module and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.
TS3	Subject locates, identifies and replaces a defective V-6401 A[5670] tube from IF Amplifier and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
TS4	Subject locates, identifies and replaces a defective Diode CR-6401 from IF Amplifier and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key .	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject complestes an Equipment Checklist. This information may be reviewed and analyzed.
TS5	Subject locates, identifies and replaces a defective V-7902 [5470] tube from Electronic Control Amplifier and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

TEST CODE	TEST DESCRIPTION	SCORING SCHEMA				DIAGNOSTICS PROVIDED
		NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	
TS6	Subject locates, identifies and replaces a defective Diode CR-7901 [IN 756] from Electronic Control Amplifier Module and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.
TS7	Subject locates, identifies and replaces a defective capacitor C-6814 from Signal Comparator Module and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
TS8	Subject locates, identifies and replaces a defective Resistor R-6821 from Signal Comparitor Module and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.
TS9	Subject locates, identifies, and replaces a defective V-6701 [5670] tube from frequency and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
TS10	Subject locates, identifies and replaces a defective Relay K-8001 from Sequential Timer Module and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The subject records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.
TS11	Subject locates, identifies and replaces a defective Diode CR424 from Relay Chassis Assembly, 3158-150 and returns the Radar Set, AN/APN-147 to an operational status.	1	1	The student records the part he found to be defective and the TA compares the subject's answer with the Answer Key.	1	The TA records in sequence the pieces of equipment that the subject requests to perform the Troubleshooting Task. The subject completes an Equipment Checklist. This information may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

TEST CODE	TEST DESCRIPTION	SCORING SCHEMA				DIAGNOSTICS PROVIDED
		NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	
SE1	Subject demonstrates usage of Signal Generator, AN/URM-25D.	1	1	The TA evaluates whether or not the subject was able to adjust the AGC Circuit using the Signal Generator.	1	None
SE2	Subject demonstrates usage of Doppler Generator CMA-546.	1	1	The TA evaluates whether or not the subject was able to place the Lock-Check Operation within tolerance limits using the Doppler Generator.	1	None
SE3	Subject demonstrates usage of Audio Oscillator TS-382.	1	1	The TA evaluates whether or not the subject was able to place the Frequency Mixer Stage Distortion within tolerance using the Audio Oscillator.	1	None
SE4	Subject demonstrates usage of 1890 M Transistor Tester.	3	1	The subject records if a transistor is good or bad. The TA compares the subject's answers with the Answer Key.	3	Subject records values obtained on his Answer Sheet. These may be reviewed and analyzed.
SE5	Subject demonstrates usage of Model TV-2 Electron Tube Test Set by testing three tubes.	3	1	The subject records if a tube is good or bad. The TA compares the subject's answers with the Answer Key.	3	Subject records all values found for each tube on his Answer Sheet. These may be reviewed and analyzed.

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
SE6	Subject demonstrates usage of PSM-6 Voltohmeter.	20	1	The subject records whether or not a given value is within + 10% tolerance with a value he obtained from use of the voltohmeter. The TA compares the subject's answers with the Answer Key.	20	Graded Elements may be reviewed and analyzed.
SE7	Subject demonstrates usage of the Tektronic 545B Oscilloscope.	8: 1)	 1	The TA evaluates whether the subject has calibrated the test probe.	8	Individual problems may be reviewed to evaluate ability to use specific scope features.
		2) 3) 4) 5) 6) 7) 8)	6 4 6 7 5 5 4	In problems 2-8, the subject sets the scope at various settings and records values obtained and tolerance status on his Answer Sheet. The TA compares the subject's answers with Answer Key.		
RR1	Subject identifies, removes and replaces Crystal, Y-6701.	1	1	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	2	None
RR2	Subject identifies, removes and replaces RF Oscillator, V-6201	1	1	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	2	None

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

TEST CODE	TEST DESCRIPTION	SCORING SCHEMA				DIAGNOSTICS PROVIDED
		NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	
RR3	Subject identifies, removes and replaces Frequency Mixer CV-1186/APN-147.	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None
RR4	Subject identifies, removes and replaces Signal Comparator CM-213/APN-147.	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None
RR5	Subject identifies, removes and replaces Sequential Timer, TD-505A/APN-147.	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None
RR6	Subject identifies, removes and replaces Crystal Mixer, CR-6702.	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

TEST CODE	TEST DESCRIPTION	SCORING SCHEMA				DIAGNOSTICS PROVIDED
		NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	
RR7	Subject identifies, removes and replaces Blower Motor Assembly, B-501.	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None
RR8	Subject identifies, removes and replaces Track Resolver Drive Assembly.	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None
RR9	Subject identifies, removes and replaces Translator Drive Assembly.	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None
RR10	Subject identifies, removes and replaces Relay, K-410	1	2	The TA records whether or not the correct item was removed and he evaluates if the item was replaced properly.	1	None

*All parts of a problem must be correct for the problem to be graded correct.

Table B1 (Continued)

		SCORING SCHEMA				
TEST CODE	TEST DESCRIPTION	NO. OF PROBLEMS	NO. OF GRADED ELEMENTS/ PROBLEM*	GRADED ELEMENT DESCRIPTION	MAXIMUM SCORE POSSIBLE	DIAGNOSTICS PROVIDED
PT1	Subject performs a soldering task on a circuit board.	2	1	The quality of the subject's soldering is evaluated by the TA and graded either acceptable or unacceptable.	2	If the quality of soldering was unacceptable, the reason is checked by the TA.
PT2	Subject identifies, removes and installs piece/parts on a Tutransitron Circuit.	3	5	The subject's performance is evaluated by TA in terms of part recognition, proper installation, and amount of heat applied.	3	TA's evaluation of subject's performance can be reviewed and analyzed.
C01	Subject performs Radar Set, AN/APN-147 Operational Check.	1	1	The TA evaluates how the subject set up the equipment and observes subject's performance on checkout procedures.	1	None.
C02	Subject performs Navigational Computer Set, AN/ASN-35 Operational Check.	1	1	The TA evaluates how the subject set up the equipment and observes subject's performance on checkout procedures.	1	None

*All parts of a problem must be correct for the problem to be graded correct.

APPENDIX C: A SAMPLE OF MATERIALS FROM TEST ADMINISTRATOR'S HANDBOOK FOR JOB PERFORMANCE TESTS (JTPT)

1. Table of Content
2. Test Administrator General Instructions
3. Test SE_7 (GE_4) Tektronic 545B Oscilloscope
    - General Instructions
    - Instructions - Problem 1
    - Instructions - Problem 5
4. Test TS-1 Troubleshooting TS-1

---

1. The complete Test Administrator's Handbook is provided in AFHRL-TR-74-57(II), Part II.

TEST ADMINISTRATOR'S HANDBOOK

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TEST ADMINISTRATOR INSTRUCTIONS

A. GENERAL INSTRUCTIONS

1. Introduction

The AN/APN-147-AN/ASN-35 test package contains a comprehensive series of tests developed to measure job performance of the electronic technician. These tests encompass all phases of day-to-day preventive and corrective maintenance that technicians are responsible for in their respective repair activities.

2. Test Administration Support Criteria

For effective test administration, it is important that ordinary support materials, such as hand tools, test equipment, etc., are readily available for the technician. Adequacy in number and serviceability is of prime importance. Sufficient time should be allotted by the Test Administrator prior to the test schedule to check prime equipment, test equipment and other required support items for reliability.

Test Administration locations will be at job sites at various installations. Each installation will vary in number of personnel to be tested; types of maintenance available; and in facilities available. All of these factors have to be considered before testing can be organized.

Test Administrators should allow sufficient time at each new Administrative Center for familiarization and test support preparation.

3. Safety

Test Administrators must observe the technician to insure that safe maintenance practices are adhered to at all times. GROUND SAFETY considerations take precedence over all others.

4. Recommended Technician - Test Administrator Ratio

The number of technicians that can be tested at once will depend on three conditions:

a. amount of test support equipment available
b. number of technicians available
c. experience of the Test Administrator

Items a and b are self-explanatory. Item c means that as the Test Administrator gains some experience giving the test, he will see ways of giving several technicians the same test at once and also ways of administering several different tests simultaneously.

5. Test Security

A number of features have been "built-in" to these tests to reduce the possibility of test compromise. For example, different forms of the same test are provided that may appear the same, but require a different answer. However, enforcement of test security is the responsibility of the Test Administrator and common precautions should be exercised:

a. Prohibit collaboration between technicians during testing.
b. Provide sufficient space between test stations for uninhibited individual work.
c. Do not permit technicians not actually engaged in testing in the test station area.
d. Insure that test instructions and all support items are accounted for at the conclusion of each test.
e. Do not leave Test Administrator's Manual unattended.

6. Organization of Test Administration Materials

Section A of this Manual provides general information on the AN/APN-147 radar and AN/ASN-35 computer. It describes the equipment, the bench set-up for checking it out, and the procedures for conducting operational checks.

The detailed instructions for administering each individual test are contained in Section B. This includes: test equipment required; test set-up procedures; technician evaluation standards; answer keys; and ways to recover from likely test situations.

Bound separately in the accompanying manual are the Technicians' Test Instructions. This contains the supply of forms, instructions, and answer sheets that the technician will receive. It is important, however, that the technician never be given this whole set of instructions. The Test Administrator is to maintain control of these instructions as well as his own. Such materials as the technician being tested needs are to be removed and provided to him individually.

The Technician's Test Instruction Manual contains:

a. a general background description of the tests
b. a background data sheet for the technician to complete
c. individual test instructions
d. alternate forms of test
e. evaluation forms for each test

The Test Administrator must select all the relevant materials from the manual, give them to the technician and insure that he gets all the materials back at the conclusion of each test. Figure 1 gives an overview of the events that are to occur in test administration. (Note: Each technician tested will complete a background data sheet only once.)

7. Evaluation Procedures

Test results are obtained in two ways in these tests -- the Test Administrator evaluates the technician's performance, and/or the technician records his findings. Answer Sheets are provided when the technician must record his findings. Performance Evaluation Sheets are provided when the Test Administrator is to evaluate performance. Supplies of both these forms, as required by each test, are provided in the Technician's Test Instruction Manual.

8. Test Administration

The PT series of tests (Peripheral Tests) can be set up in a separate area from the actual-work location where the other tests will be administered. This area, however, should be relatively close and easily reached. The tests in the PT series can then be set up in a "country fair" fashion and technicians rotated through them as they come from or go to the other test area (actual work location).

All of the other test series will be administered to technicians at their normal work stations. This is to insure that the technician has available his normal supply of equipment, tools, references, etc. Under good conditions, where each technician has a set of prime equipment, he should be given the test series in the following order: GE, CO, SE, RR, AD, AL, TS, with the PT series taken as convenient. When there is a shortage of equipment, it will be necessary to utilize the available equipment as availability dictates. For example, if there was only one available prime equipment test set, then only one series could be run at a time and test scheduling would have to be set up accordingly. In this case, test security has to be carefully attend to, since there is a greater possibility of exchange of information among technicians. Greater use of the alternate test forms would be required than under conditions of simultaneous testing.

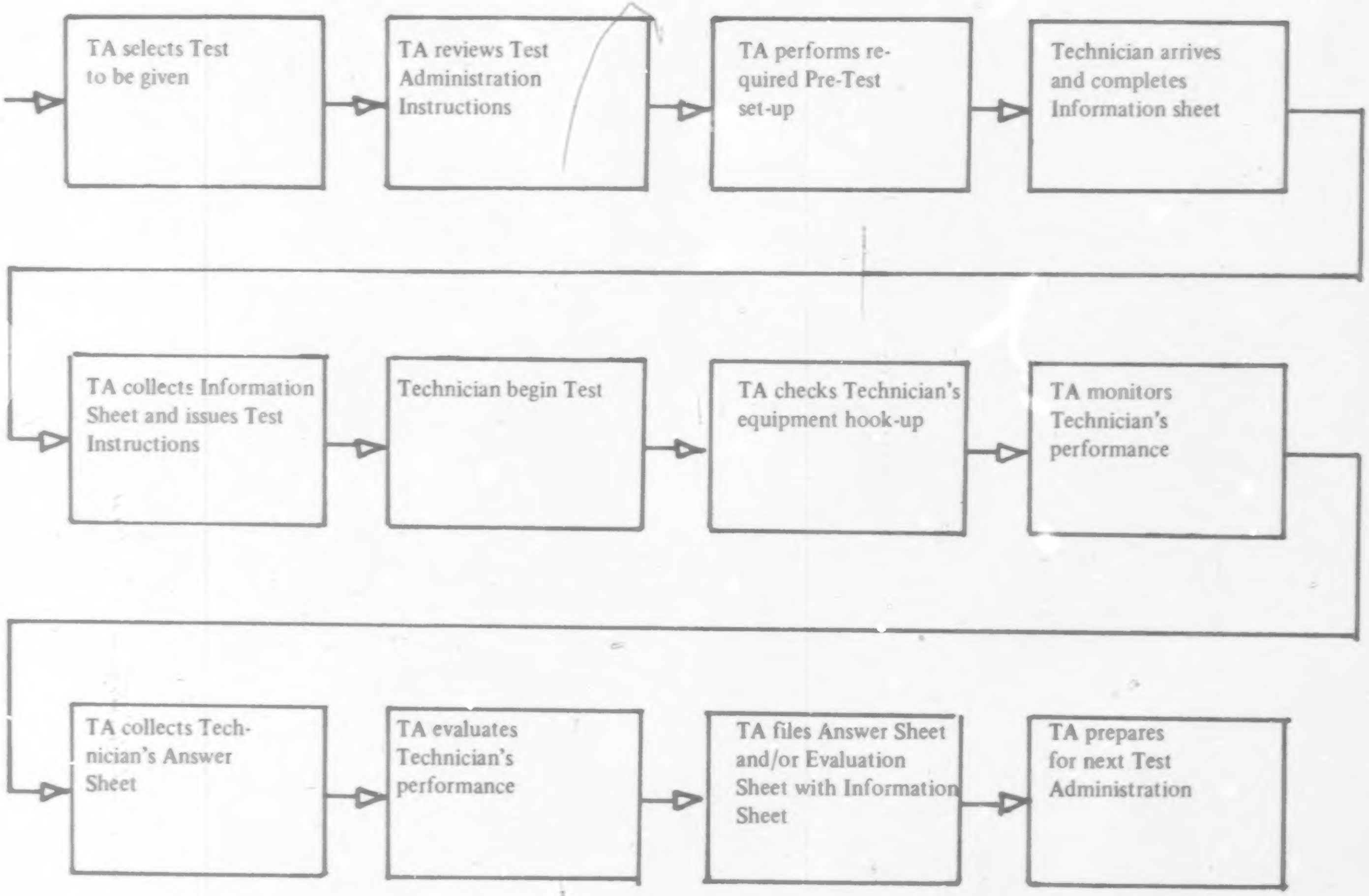

TA selects Test to be given
TA reviews Test Administration Instructions
TA performs required Pre-Test set-up
Technician arrives and completes Information sheet
TA collects Information Sheet and issues Test Instructions
Technician begin Test
TA checks Technician's equipment hook-up
TA monitors Technician's performance
TA collects Technician's Answer Sheet
TA evaluates Technician's performance
TA files Answer Sheet and/or Evaluation Sheet with Information Sheet
TA prepares for next Test Administration

Figure C1. **Typical sequence of events in Test Administration.**

9. Test Recovery Guides

It is probable that situations will arise where technicians will unintentionally grossly misalign the prime equipment. A variety of guides are included to serve as short-cuts for the Test Administrator to return the equipment to an operational status. While it is important to get the equipment functioning at the best level possible, it was not feasible to gear the creation of these guides towards absolute peak performance. Such items as the trimpot settings and the template for coils, as they appear in the guides, are relative to the different equipment systems being used. Thus, it is anticipated that although the guides will not enable the Test Administrator to "perfectly" align the equipment, they will enable him to render the equipment "operational."

TEST ADMINISTRATOR INSTRUCTIONS

TEST

GE-4, Tektronic 545B Oscilloscope

TIME ALLOTTED

60 minutes

SUPPORT MATERIALS REQUIRED

a. Tektronic 545B Oscilloscope with CA plug-in (1)

b. Two 10:1 Probes (2)

c. Instruction manuals for oscilloscope and plug-in

d. Waveform Generator Console (3) (special test box)

PRE-TEST SET-UP

a. Insure that the above listed materials are available at each of the testing stations to be used.

b. There are three versions of this test - Forms 1, 2, & 3. Each contains eight problems.

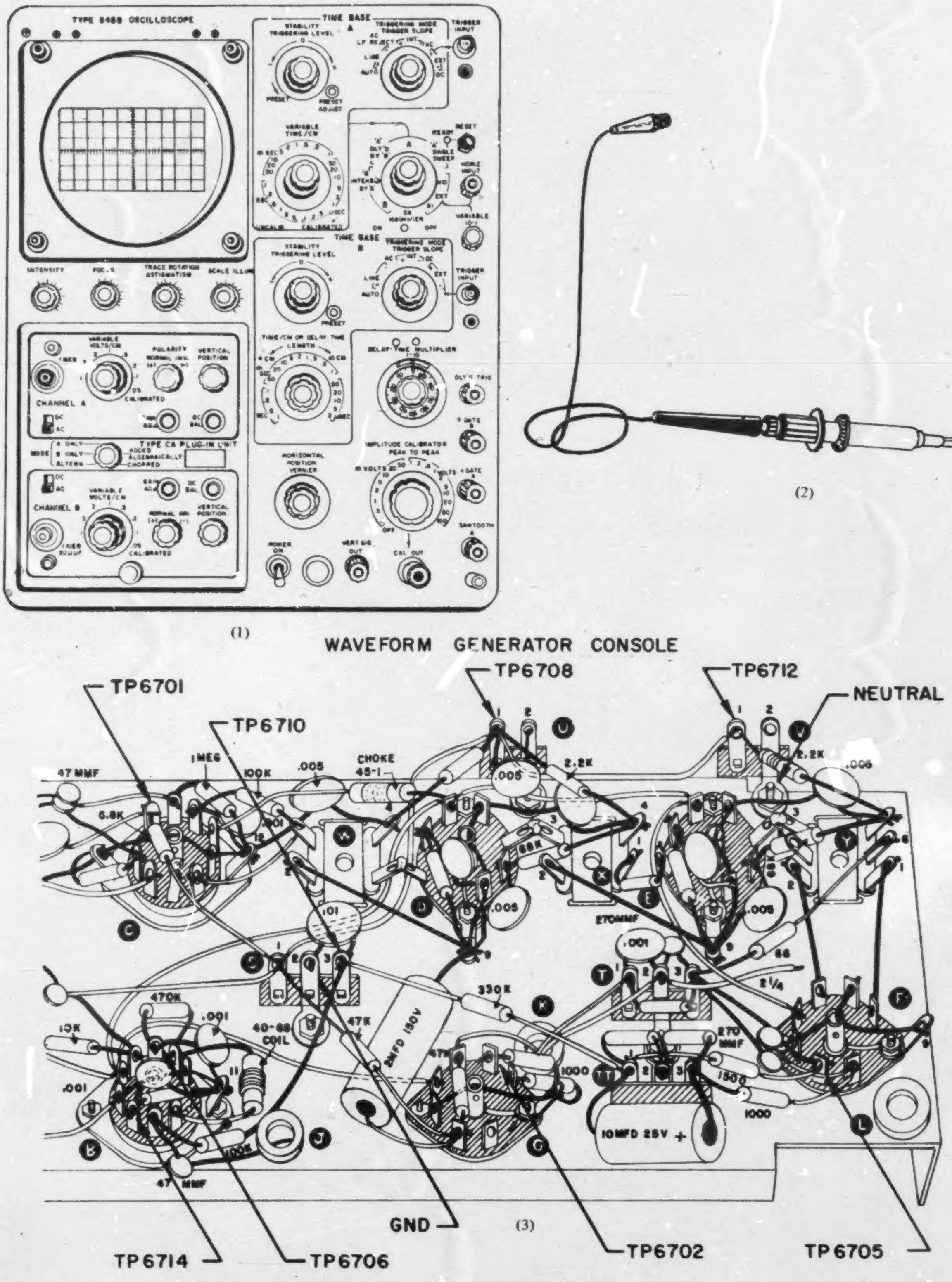

TYPE 546B OSCILLOSCOPE
TIME BASE A
STABILITY
TRIGGERING LEVEL
TRIGGERING MODE
TRIGGER SLOPE
TRIGGER INPUT
PRESET
PRESET ADJUST
VARIABLE TIME/CM
RESET
READY
SINGLE SWEEP
HORIZ INPUT
MAGNIFIER
VARIABLE
CALIBRATED
TIME BASE B
INTENSITY
FOCUS
TRACE ROTATION ASTIGMATISM
SCALE ILLUM
VARIABLE VOLTS/CM
POLARITY
VERTICAL POSITION
CHANNEL A
TYPE CA PLUG-IN UNIT
A ONLY
B ONLY
ALTERN
ADDED ALGEBRAICALLY
CHOPPED
MODE
CHANNEL B
TIME/CM OR DELAY TIME
DELAY-TIME MULTIPLIER
DLY'D TRIG
HORIZONTAL POSITION VERNIER
AMPLITUDE CALIBRATOR PEAK TO PEAK
+GATE
SAWTOOTH A
POWER ON
VERT SIG OUT
CAL OUT
(1)
(2)
WAVEFORM GENERATOR CONSOLE
TP6701
TP6710
TP6708
TP6712
NEUTRAL
47 MMF
6.8K
1MEG
100K
.005
CHOKE 45-1
2.2K
.001
68K
270MMF
.01
330K
47K
2MFD 150V
470K
10K
40-68 COIL
1000
1500
270 MMF
10MFD 25V +
47 MMF
GND
(3)
TP6714
TP6706
TP6702
TP6705

Figure C2. **Equipment required for oscilloscope tests.**

c. If several technicians are being tested at once, give different forms of the test to adjacent technicians.

d. If technicians are being tested one after the other, give different forms each administration.

e. Decalibrate the test probe by loosening the collar (see opposite page) and turning the sleeve 1/2 turn counter-clockwise. Retighten the collar.

TEST ADMINISTRATION PROCEDURES

a. Have the technician read his instructions for test GE-4.

b. Note the time and instruct the technician to begin the test.

PERFORMANCE EVALUATION PROCEDURES

a. Problem 1.

1. This problem consists of calibrating the test probe. It is the same on all forms of the test.

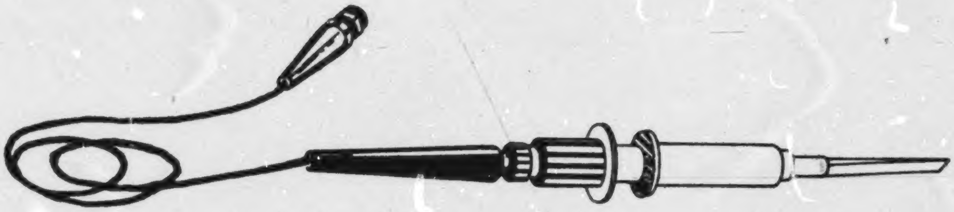


Figure C3. **Scope Probe.**

2. When the technicians has calibrated the probe, collect his Instruction Sheet for Problem 1.

3. Compare the indication that the technician has obtained on the oscilloscope with that shown on the Answer Key (see opposite page).

4. If the probe has been properly calibrated:

    - Check "YES" on the Performance Evaluation portion of the Instruction Sheet

    - Instruct the technician to continue the test.

5. If the probe has not been properly calibrated:

    - Check "NO" on the Performance Evaluation portion of the Instruction Sheet

    - Assist the technician to properly calibrate the probe

    - Instruct the technician to continue the test.

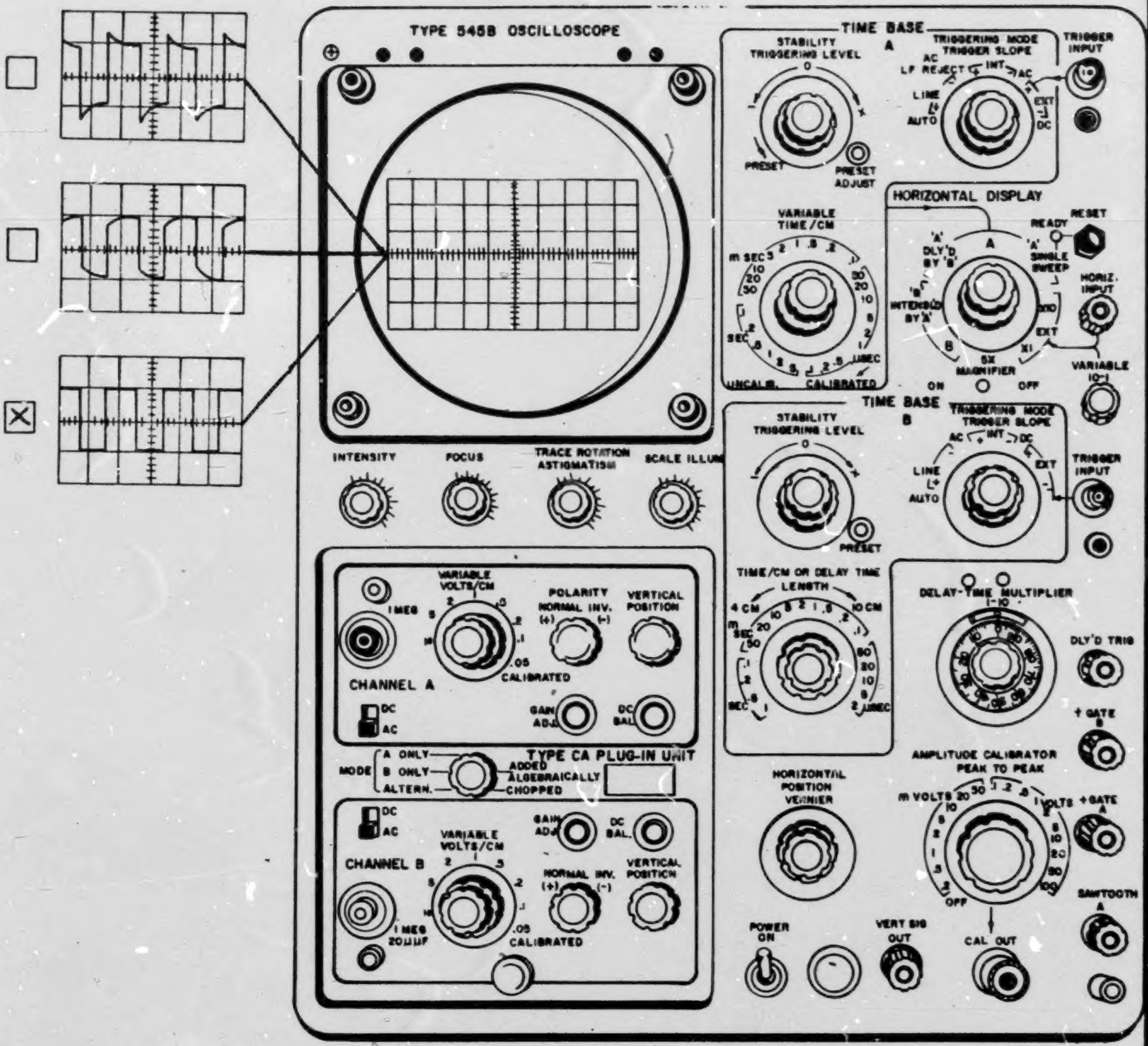

☐
☐
☒
TYPE 545B OSCILLOSCOPE
TIME BASE A
STABILITY
TRIGGERING LEVEL
PRESET
PRESET ADJUST
TRIGGERING MODE
TRIGGER SLOPE
AC
LF REJECT
INT
LINE
AUTO
EXT
DC
TRIGGER INPUT
VARIABLE TIME/CM
m SEC
SEC
μSEC
UNCALIB.
CALIBRATED
HORIZONTAL DISPLAY
READY
RESET
'A' DLY'D BY 'B'
'A' SINGLE SWEEP
'B' INTENSIFIED BY 'A'
EXT
5X MAGNIFIER
ON
OFF
HORIZ. INPUT
VARIABLE 10-1
TIME BASE B
STABILITY
TRIGGERING LEVEL
PRESET
TRIGGERING MODE
TRIGGER SLOPE
TRIGGER INPUT
TIME/CM OR DELAY TIME
LENGTH
4 CM
10 CM
DELAY-TIME MULTIPLIER
DLY'D TRIG
+ GATE B
AMPLITUDE CALIBRATOR
PEAK TO PEAK
m VOLTS
VOLTS
OFF
+ GATE A
SAWTOOTH A
CAL OUT
VERT SIG OUT
POWER ON
HORIZONTAL POSITION VERNIER
INTENSITY
FOCUS
TRACE ROTATION
ASTIGMATISM
SCALE ILLUM
VARIABLE VOLTS/CM
POLARITY
NORMAL INV.
(+)
(−)
VERTICAL POSITION
1 MEG
CHANNEL A
CALIBRATED
DC
AC
GAIN ADJ.
DC BAL.
MODE
A ONLY
B ONLY
ALTERN.
ADDED ALGEBRAICALLY
CHOPPED
TYPE CA PLUG-IN UNIT
CHANNEL B
1 MEG 20μμF

Figure C4. **Typical scope pattern answer presentation.**

b. Problems 2 through 8

1. When the technician has completed the problems, collect his Instructions and Answer Sheets and insure that his identification number is on them.

2. Compare his answers to the Answer Key for that form (see pages 119 to 165).

3. Each problem has two parts:

   (a) Is the signal within tolerance?
   (b) What control settings were used?

4. Part (a) is to be answered at the bottom of the Instruction Sheet. If it is answered incorrectly, mark it with an "X".

5. Part (b) is answered on a second sheet. Check the settings used to see that they are the same as those on the Answer Key.

6. Where the Answer Key indicates "N/A", disregard the technicians settings. These are irrelevant settings.

7. Mark any other answers that are wrong with an "X":

TEST ADMINISTRATOR ANSWER KEY 1

GE-4, PROBLEM 5, FORM 1

PROCEDURES:

a. Channel "A" on the oscilloscope will be used for this problem.

b. Ground the oscilloscope to the "Ground" connection indicated on the Waveform Generator Console.

c. Set the sweep to display seven pulses of the waveform present at Test Point 6710 on the Waveform Generator Console.

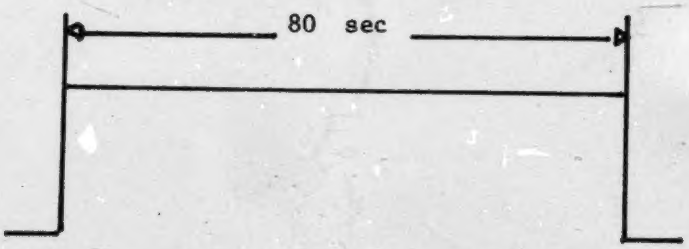
d. Utilize the delayed pulse feature to display the center pulse (4th positive going pulse from the left) in the center of the graticule.

e. Compare all of the resultant values of the waveform on the oscilloscope with the one shown below to determine if it is within tolerance of ± 10%.

f. Mark the appropriate answer box below to indicate whether the Test Point waveform is in or out of tolerance.

g. Record your selected scope control settings on the Oscilloscope Control Setting Answer Sheet.

h. Return your answer sheet to the Test Administrator and go to the next problem.



Within Tolerance X

Out of Tolerance ____

TEST ADMINISTRATOR ANSWER KEY 2

GE-4, PROBLEM 5, FORM 1

OSCILLOSCOPE CONTROL SETTING

CONTROL	SETTING
Trigger Mode (Time Base A)	Any setting except Auto
Horizontal Display	"A" Dly'd by "B"
DELAY Multiplier (Read-out)	Approximately 4:60
Stability (Time Base A)	Fully Clockwise
Time/CM (Time Base A)	10 usec
Time/CM (Time Base B)	.1 msec

TEST ADMINISTRATOR INSTRUCTIONS

TEST

TS-1, Frequency Tracker Power Supply Troubleshooting

TIME ALLOTTED

60 minutes

SUPPORT MATERIALS REQUIRED

a. Bench test set-up as described in Section A, Part IV.

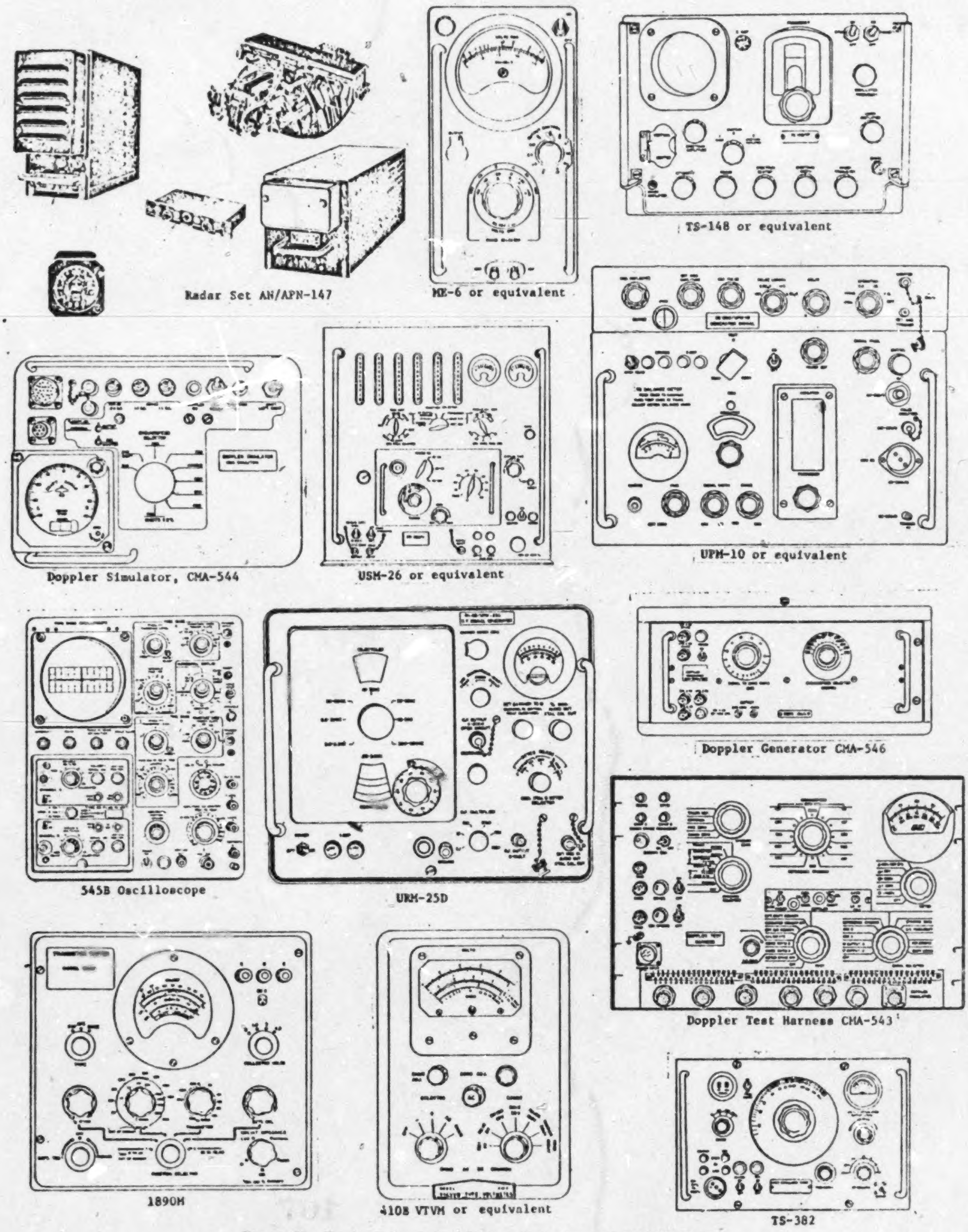
b. Test Equipment, to be available upon request. (See opposite page.)

c. Hand Tools

d. Defective 6080WA Tube

PRE-TES SET-UP

a. Perform an operational checkout of the Radar set to insure that it is functioning properly. Use the procedures outlined in Section A, Part V.



Radar Set AN/APN-147

ME-6 or equivalent

TS-148 or equivalent

Doppler Simulator, CMA-544

USM-26 or equivalent

UPM-10 or equivalent

545B Oscilloscope

URM-25D

Doppler Generator CMA-546

Doppler Test Harness CMA-543

1890M

410B VTVM or equivalent

TS-382

Figure C5. **Equipment required for bench checkout of AN/APN-147.**

TS-1

b. Remove operative V-7207 (tube 6080WA) from Frequency Tracker Power Supply (see opposite page).

c. Install the defective 6080WA tube in V-7207.

d. Review the technician's Test Instructions to familiarize yourself with them.

TEST ADMINISTRATION PROCEDURES

a. Have the technician read his instructions and put his identification number on his Answer Sheet and Performance Evaluation Sheet.

b. Collect the technician's Performance Evaluation Sheet.

c. Note tthe time and have the technician begin the test.

d. When the technician wants to replace a suspected faulty part or module, he must remove it from the set (WITHOUT UNSOLDERING ANY COMPONENTS) and bring it to you.

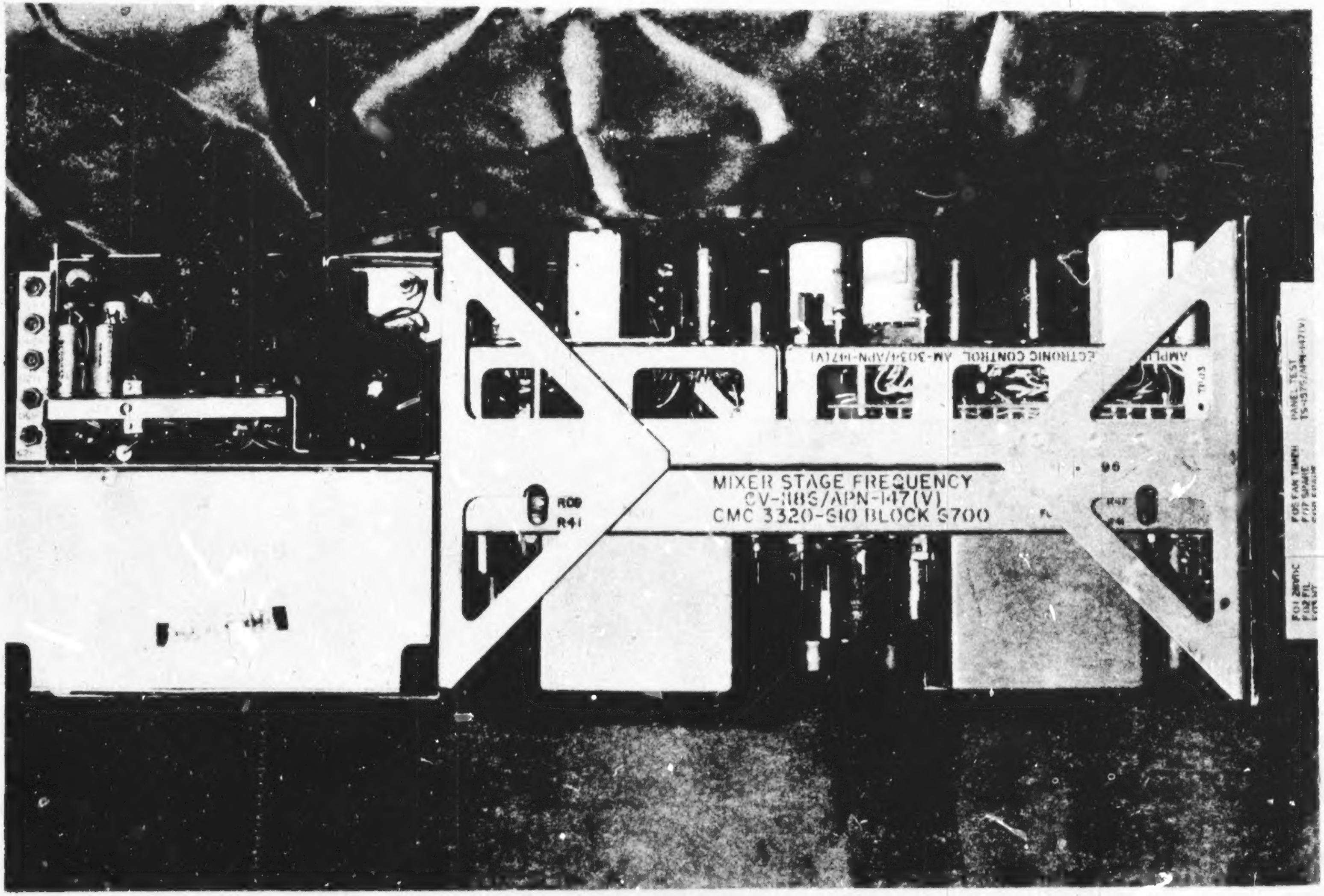

MIXER STAGE FREQUENCY
CV-1185/APN-147(V)
CMC 3320-SIO BLOCK S700
AMPL
ECTRONIC CONTROL AM-3034/APN-147(V)
TP-03
R08
R41
PANEL TEST
TS-1575/APN-147(V)

Figure C6. **Frequency tracker power supply.**

e. When the technician requests a replacement component, he must specify the exact piece/part that he wants replaced.

f. If the technician has not properly specified the part he wants replaced on the module he has turned in, make him re-specify.

g. Once you are satisfied with the request, you either:

   1. Go to a remote area and exchange the module or part turned in for the good one, if the technician has identified the faulty part;

      OR

   2. Go to a remote area and simulate the exchanging of one module or part for another, if the technician has not identified the faulty component.

h. Return the module or part to the technician and inform him that the part he requested is now good.

i. Mark the part requested in sequence (1, 2, 3, etc.) on the technician's Performance Evaluation Sheet.

j. When the technician has completed the test or time has elapsed, collect his Answer Sheet.

PERFORMANCE EVALUATION PROCEDURE

a. When the technician turns in his answer sheet, compare his answer with the correct one.

b. Mark the technician's answer with an "X" if it is wrong.

c. Fasten the technician's Answer Sheet and Performance Evaluation Sheet together, insuring that his identification number is on both.

POST-TEST RECOVERY

a. If the technician has found and corrected the malfunction inserted into the equipment, perform an operational checkout to insure proper equipment functioning.

b. If the technician was unable to repair the radar set, correct the fault by re-installing the good tube (see page 421).

c. Perform an operational checkout.

d. If equipment is still malfunctioning, request assistance from local support.